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The De-Evolution of Space: A Vision for Combat Capable Space Systems

Major Jeffrey L. Caton, USAF

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.

Giulio Douhet [1]

Introduction

The words of Douhet are often quoted, but rarely followed. The US is not properly anticipating the future character of war in space, despite clear indications of its importance as demonstrated in recent conflicts. I will argue that current spacelift assets cannot provide adequate support for force enhancement assets in a combat environment, and that this deficiency can best be resolved by a new approach—de-evolution. This solution presents a paradigm shift which, when applied to spacelift and satellite design, can greatly benefit space operations. This essay does not propose specific systems to solve our combat deficiencies in space, but rather, it provides a vision toward the solution.

Needs and Shortfalls

Military Space Operations

Space systems have supported operational commanders for over three decades.[2] From the Missile Defense Alarm System (MIDAS) in the early 1960s, to the current array of weather, communication, navigation, and surveillance satellites, the US warfighter has come to depend on space assets in times of war and peace. US military strategy calls for "an extensive space capability" with "a wide variety of space systems."[3] This dependency on space assets presents a vulnerability that a competent foe cannot afford to ignore.

Space systems face many challenges during military operations. The proliferation of space technology may allow future adversaries to degrade or destroy our satellites. Also, unanticipated system failures and multiple area coverage requirements may require the immediate placement of satellites into orbit. To accomplish this, *spacelift is essential to space operations*. It must ensure space systems are on orbit when and where the warfighter needs them.

Threats

Are there any countries that can pose a threat in space? Absolutely. Not including those countries with established space programs (Unites States, Former Soviet Union, France, Japan, and China), there are at least 22 countries with active ballistic missile programs, 9 of which are also pursuing space launch vehicle (SLV) capabilities.[4] The emergence of space warfare capabilities by other countries seems not to be "if," but rather "when."

The key space threat still resides in the Former Soviet Union (FSU)—Russia. Russia has retained 90% of the FSU space industry, including two of the three launch complexes.[5] Russia also possesses four anti-satellite-capable systems,[6] and their current military doctrine clearly shows their willingness to use them.[7]

Deficiencies

Considering the importance of spacelift to future warfighters, it is surprising it does not receive more emphasis. Of the four combat media—land, sea, air, and space—only in space has the US *consciously allowed itself to be inferior in warfighting capability*. We have an illusion of superiority, thinking that superior technology equates to superior combat capability. "Our capability to accomplish force enhancement from space is superior to that of the Soviets [now FSU]—but only during hostilities that do not place the satellites themselves under attack."[8] In future conflicts, the US cannot afford to assume that our space assets will not be interfered with. Planners need to factor in satellite attrition, just as surface and air force attrition is included in today's planning.

Can the US endure a war of attrition in space? Recent experience indicates that we cannot. During the Falklands War, the Soviet Union conducted 29 satellite launches within 69 days—an extraordinary surge capability.[9] In contrast, the US took 113 days to replace a defense weather satellite after an emergency call.[10] In the future, it is likely that a major regional conflict will be fought and won (or lost) in much less than 113 days. How can the US resolve this combat deficiency in space support?

Combat Capable Spacelift

Evolution Versus Revolution

For the most part, our current SLVs are derivatives of ballistic missiles, incorporating 30 to 40 year-old technology that was never designed to deliver satellites to orbit.[11] The satellite community has driven for ever-increasing demands on the performance and physical configuration of the boosters, turning many SLV flights into research and development milestones.[12] This methodology often pushes the design limits of the vehicle, thus reducing its margin for error,[13] and making each launch very risky. To help reduce this risk, an elaborate vehicle processing support network is used. This network often requires unique test equipment and procedures, and it is usually manned by an army of contractor engineers and technicians. This methodical, "check everything twice" approach may reduce risk, but it requires long schedules and great operating costs.

This evolutionary approach to these SLVs has developed well beyond the point of diminishing return, requiring great expense for incremental performance increase. This continued pursuit of "one more modification" is a cancer upon our nation's space force, with a tremendous appetite for resources which when fed, only makes the system weaker. It is time to break this vicious cycle—but how?

A more radical approach to spacelift is to pursue exotic technologies that will offer revolutionary performance increases. Anti-matter, anti-gravity, electromagnetic, and other

such propulsion technologies may be available in the distant future. However, existing spacelift deficiencies require immediate attention if we are to provide combat space support to warfighters. If neither the evolutionary nor the revolutionary approach can resolve spacelift deficiencies, what can?

The De-Evolution of Spacelift—A Paradigm Shift

The primary problem with our current spacelift system is that it ignores a fundamental truth—*no one can build a perfect system.* Murphy's Law will always apply, and during war it will be augmented by Clausewitzian fog and friction. Our current spacelift operations seem to embody the belief that if enough money, studies, people, and quality assurance are thrown at a system, it will become perfect. However, this approach overlooks another fundamental truth—a system does not need to be perfect if it is designed to be *robust and fault-tolerant.* Applying these two truths to our spacelift shortfalls points to a solution that is away from our current systems and toward the technologically "inferior" systems of the FSU:

> If the Soviets use technology that is primitive by our standards but meet their mission requirements while we fail to satisfy ours, then their technology is better by any sensible standard of military utility. . . . In fact, if the cruder Soviet system allows greater latitude for error and thereby yields greater reliability, then for all practical purposes it is a better system.[14]

This backing away from current razor-thin, high-technology design margins, toward the "duct-tape-it-before-launch" approach of the FSU, represents a significant paradigm shift—a "de-evolution" of technology that is required to increase *operational utility.* This approach can lead to a rapid response spacelift system that emphasizes standardized procedures, short sortie generation times, robust design margins, and simplified launch site operations.

Is this saying that advances in technology are bad? Certainly not; but the application of these advances must be balanced against operational utility and design margin. Just because a system can be designed within 1% of structural failure does not mean it has to operate that way. Engineers may need to throw away their complex computational fluid dynamics design software and learn to use a slide rule again—the point being that common sense and intuition should be emphasized over blind faith in computer simulations. Technicians and maintenance personnel should also have a say in the design process to help reduce complexity of operations.

De-Evolution: An Example

To better understand the concept of de-evolution, consider the common automobile. Almost all new model cars use fuel injection and electronic ignition versus the mechanical carburetor and distributor ignition systems of yesteryear. The new models offer better fuel economy and more optimized performance—but only when the modules are working. When they fail, they tend to do so in a catastrophic manner, leaving the car "dead in the water." Repair work is expensive and requires specialized training and support equipment; it is beyond the capability of the average operator.

On the other hand, the older cars offer greater operational utility. Their robust systems tend to degrade before total failure, allowing the operator ample time to bring the car to a service station. In many cases, the repairs can be performed by an operator with basic system knowledge, and less support equipment is required. Because of their simplicity and standardization, replacement parts are usually less expensive also. Obviously, the newer model cars will deliver superior performance when they are operating. However, when Murphy's Law crops up, the older ("de-evolved") cars are the best bet to provide basic transportation that is fault tolerant and easy to maintain—superior operational utility.

Combat Capable Satellites

Light Satellites (LightSats)

The de-evolution of spacelift could fundamentally change US space operations, but only if it is coupled with a parallel de-evolution from complex, heavy, long-life satellites to simpler, smaller, shorter life satellites (LightSats).[15] In warfighting terms, the big satellites are like B-17s in space—self-defending, capable, and an easy target for a determined foe. In contrast, the use of LightSats, coupled with a rapid response spacelift system, could dramatically increase space combat capability. Using a capability-driven design approach,[16] LightSats could ensure maximum utilization of existing technology and provide a more flexible response to threats. Increased space sortie generations could provide near real-time response to warfighter force enhancement requirements. The shorter-life LightSats could actually be *more capable* since they could incorporate improvements more rapidly than the longer-life satellites, and they would contain fewer redundancies. If systems are required that exceed the payload capability of the SLVs, on-orbit assembly of these larger satellites could be pursued. If a given subsystem does not checkout on orbit, or if it fails during operation, it can be replaced using the rapid response spacelift.

There are challenges to the LightSat approach, however. The use of smaller satellites in a distributed constellation would increase the complexity of the command and control architecture.[17] Also, even if the rapid response spacelift becomes a reality, satellite on-orbit checkout times must also be reduced to ensure improved combat capability. Both of these issues must be considered in the design process.

Risk Reduction Versus Risk Distribution

Under the evolutionary approach to space operations, risk reduction was accomplished by tedious quality assurance checks and extensive system redundancies. One of the greatest benefits of a rapid spacelift/LightSat approach is that operational risk is distributed; the dilemma of "all the eggs in one basket" is avoided. This concept of risk distribution can prevent the recurrence of previous billion-dollar losses, such as the Titan IV SLV incident of August 1993.[18] Also, this concept will drastically reduce the need for quality checks and redundancies, thereby reducing procurement and operating costs.

Military First

Contrary to the recommendations of numerous spacelift studies that have been conducted since the *Challenger* disaster, combat capable space systems should be pursued without the influence of civil and commercial interests. While civil and commercial space programs entail large expenditures, they represented only 0.24% of the 1992 gross domestic product[19]—hardly a threat to US economic viability. In contrast, existing and proliferating foreign military space capabilities present a feasible threat to US national security. This is not to say that civil and commercial space industry cannot benefit from the more capable military systems produced through de-evolution. However, their benefit should be derived only after the military system has been established. To do otherwise would open the door to a long and complex consensus-building process that would further delay the deployment of a critical combat capability.[20]

Summary

Some US military space systems may not be able to support warfighters during conflicts that extend into space—a distinct future possibility. To resolve this deficiency, one option would be that systems must break away from the obsolete evolutionary design process and change to an approach that emphasizes operational utility in balance with technology. This de-evolution of space systems to less complex, more robust, rapid response spacelift and LightSats offers true space combat capability.

Notes

1. Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari, reprint of 1942 ed., Office of Air Force History, Washington, DC, 1983, p. 30.
2. Lt Gen Thomas S. Moorman, Jr., USAF, "Space: A New Strategic Frontier," *The Future of Air Power in the Aftermath of the Gulf War*, ed. Richard H. Schultz, Jr. and Robert L. Pfaltzgraff, Jr., Air University Press, Maxwell Air Force Base, AL, 1992, p. 236.
3. *National Military Strategy of the United States,* Joint Chiefs of Staff, The Pentagon, Washington, DC, January 1992, p. 23.
4. Maj Thomas A. Torgerson, USAF, *Global Power Through Tactical Flexibility: Rapid Deployable Space Units*, Airpower Research Institute Research Report, Air University Press, Maxwell Air Force Base, AL, June 1994, Table 3. The 22 countries mentioned are (asterisk indicates SLV program): Afghanistan, Algeria, Argentina, *Brazil, Cuba, Egypt, *India, *Indonesia, Iran, *Iraq, *Israel, Kuwait, Libya, North Korea, *Pakistan, Saudi Arabia, *South Africa, *South Korea, Syria, *Taiwan, Vietnam, and Yemen.
5. Lt Col Gregory A. Keethler, USAF, *The Impact of the Soviet Union's Demise on the US Military Space Program*, Air War College Research Report, Air University, Maxwell Air Force Base, AL, 19 April 1993, p. 2.
6. *Soviet Military Power Prospects for Change 1989*, Government Printing Office, Washington, DC, 1989, pp. 54-56. The four anti-satellite systems are: co-orbital, antiballistic missiles, ground-based lasers, and electronic warfare assets. In addition to the four anti-satellite systems mentioned, the FSU have been engaged in research for over three decades to develop directed-energy weapons, which include space-based options.
7. Mary C. Fitzgerald, "Russia's New Military Doctrine," *RUSI Journal*, October 1992, p. 44. One of the seven priorities of the Russian Armed Forces is military space systems. Also, achieving space superiority is listed as a prerequisite for the use of ground troops in a conflict.
8. Maj Gen Robert R. Rankine, Jr., USAF, "The US Military Is Not Lost in Space," *Building a Consensus Toward Space: Proceedings of the Air War College 1988 Space Issues Symposium*, Air University Press, Maxwell Air Force Base, AL, April 1990, p. 48.
9. Lt Col Stephen J. Dunning, USAF, *U.S. Military Space Strategy*, The United States Naval War College, Newport, RI, 14 May 1990, p. 9.
10. Gen John L. Piotrowski, USAF, address to the Michigan State Air Force Association Convention, East Lansing, MI, 28 July 1989. The example in the text refers to the replacement of a Defense Meteorological Support Program satellite which failed in September 1987. On 13 October 1987, an emergency launch call was issued. The replacement satellite was launched 3 February 1988—113 days after the emergency call and 153 days after the failure.
11. *Ten-Year Space Launch Technology Plan,* Department of Defense, National Aeronautics and Space Administration, and Department of Energy, Washington, DC, November 1992, p. ES-1.
12. Lt Col Randall G. Joslin, USAF, *Spacelift—A National Challenge for USSPACECOM*, Air War College Associate Programs Research Report, Peterson Air Force Base, CO, 21 June 1993, p. 8.
13. Philip Kunsberg, "Space Infrastructure," *Building a Consensus Toward Space: Proceedings of the Air War College 1988 Space Issues Symposium*, Air University Press, Maxwell Air Force Base, AL, April 1990, p. 66.
14. Ibid., p. 62.
15. Statement by Gen Charles A. Horner, USAF, in "Space Seen As Challenge, Military's Final Frontier," unclassified testimony before the Senate Armed Services Committee, 22 April 1993, reported in *Defense Issues*, vol. 8, no. 34, p. 5. Gen Horner drew a clear connection between SLV design and satellite design: "Any worthwhile change in launch philosophy will also dictate a fundamental shift in the existing satellite design mindset."
16. S. Roy Schubert, James R. Stuart, and Stanley W. Dubyn, "LightSats: The Coming Revolution," *Aerospace America*, February 1990, p. 28. In the capabilities-driven design approach, mission requirements are compared with available technology to eliminate potential requirements for new technology developments that would become the critical path.
17. Donald C. Latham, "Lightsats: A Flawed Concept," *Armed Forces Journal International*, August 1990, p. 84.
18. Bruce A. Smith, "Explosion Halts Titan 4 Launches," *Aviation Week & Space Technology*, 9 August 1993, p. 22. On 2 August 1993, a Titan IV launch from Vandenberg AFB exploded at 101 seconds into its flight. The cost of the failure is estimated to be between one and two billion dollars. The effects of this incident go beyond just the economics; it "put Titan 4 launches on hold and threatens further delays in the deployment of key national security spacecraft."
19. Lt Col Larry D. James, USAF, *Dual Use Alternatives for DOD Space Systems*, Air War College Research Report, Air University, Maxwell Air Force Base, AL, April 1993, p. 17.
20. An example of spacelift consensus building gone awry: The pursuit of a "next generation" spacelift system has been so mired in politics that it has done little more than change names from "Advanced Launch Development Program" to "Advanced Launch System" to "National Launch System" to its most recent incarnation — "Spacelifter" (this constant change has prompted some to ironically refer to the program as "Shapeshifter").

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Note: This article was the winner of the 1994 United States Space Command Operational Art of Space Warfare Essay Contest.

Most Significant Article Award

The Editorial Advisory Board has selected "A Logistics Life Cycle Cost Guide for the Program Manager" by Colonel Martin D. Carpenter, USAFR, as the most significant article in the Spring-Summer 1994 issue of the *Air Force Journal of Logistics.*

Most Significant Article Award

The Editorial Advisory Board has selected "A Case for Eliminating the Initial Provisioning of Spares" by Charles F. Youther, as the most significant article in the Fall 1994 issue of the *Air Force Journal of Logistics.*

Evolution of Space System Support

William T. Baylis, PhD

This paper is an attempt to redirect the readers' thinking in terms of how to develop and implement a Logistic Support Analysis (LSA) program for today's "high technology" space systems. It addresses some of the requirements for supporting the Space Station *Freedom* program arrived at by rethinking the "traditional" LSA process.

Introduction

Space systems represent undertakings of massive proportions that introduce requirements, concerns, and constraints resulting in new applications of existing procedures and methodologies, including LSA. This realization came about on the current space station program.

Even though the goals of the "traditional" LSA remain relatively unchanged, the LSA effort on the space station program has resulted in recognizing that issues and concerns have surfaced that make it imperative to "reassess" the way the LSA needs to be conducted on current and future space programs.

An example of looking at a program requirement differently from the traditional viewpoint is with mean time to repair (MTTR). When comparing an organizational task's MTTR between a major weapon system and a space system (B-1B bomber versus space station), one can see a great disparity in times. For the B-1B bomber, there was a requirement that the MTTR at the flight line was not to exceed (NTE) 20 minutes. For Space Station *Freedom* there is a program requirement that the MTTR of an extravehicular activity (EVA) task is NTE six hours (Table 1). This includes all associated preparatory task steps.

Traditional LSA

Hardware

The traditional LSA embraced hardware and did not consider software requirements. Additionally, the hardware was analyzed from a physical viewpoint and did not look at functional implications. This approach failed to consider reliability and maintainability aspects (rolling up the failure rate of an LRU into its associated function). Failure of the Antenna Assembly (Figure 1) should be depicted as part of the Communications System (functional breakdown) since a failed antenna has a direct impact on the communication system, not on the right wing (Figure 2).

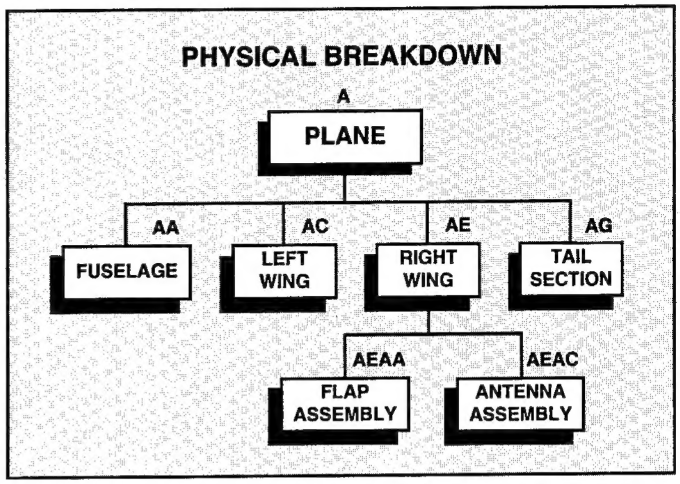

Figure 1. Traditional Example of a Logistics Support Analysis of a Weapon System.

MIL-STD-1388-2B has addressed and corrected this. The result is the addition of the LSA Control Number (LCN)-type data element, utilizing a "P" for physical and an "F" for functional.

Software

Over the past few years, major weapon systems and electronic systems have become software intensive. This is very apparent for space systems which are positioned, activated, and repaired (limited) via software programs. It seems apparent that software developers need to make more use of "reusable" code. This represents code that is written once and possesses multiple uses. As more space systems are developed, code written and debugged for one system can be reused on other systems. This demonstrates the need for standardization and modularity of

SYSTEM	TASK	MTTR	RATIONALE
B-1B Bomber	Remove/Replace Line Replaceable Unit (LRU) (organizational maintenance level)	20 Min.	Aircraft (major weapon system): Need to get the aircraft off the ground as soon as possible. Remove and replace the suspect LRU.
Space Station	Remove/Replace Orbital Replaceable Unit (ORU) (organizational maintenance level)	6 Hr.	Space Station: Orbiting platform located in an extremely hostile environment (no air, meteorites, debris). Suit is self-contained and has time constraints imposed on it. Remove and Replace the known failed ORU.

Table 1. Mean Time to Repair (MTTR) Comparisons.

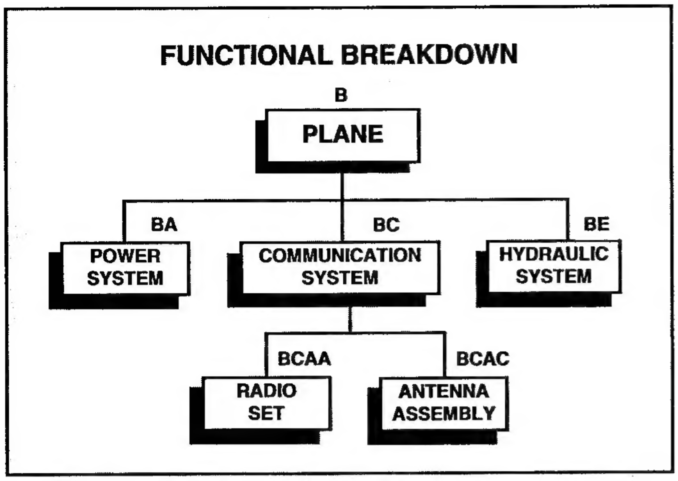

Figure 2. Modified Example of a Logistics Support Analysis of a Weapon System.

software. Standardization of parts (hardware application) has been in effect for a number of years.

Also, there needs to be more work done in the area of artificial intelligence in terms of software being able to maintain and correct itself. This can be seen if one understands that space system software is embedded in the control/monitoring subsystems for orbit-sustaining critical mechanical and electronic systems.

Computer hardware and associated software technology is advancing so rapidly that technology which is state-of-the-art when systems are in design are often obsolete by the time they are deployed (Figure 3).

Reliability and maintainability are used in software development; however, many individuals try to view these areas in the same light as hardware. Table 2 depicts the difference between reliability and maintainability for hardware and software.

When considering LSA and associated analyses for assisting in the design and development of supportability for space systems, it is imperative to rethink the way LSA is conducted. Due to the nature of the operational environment, traditional LSA will not completely satisfy the determination of all supportability requirements for space systems.

When analyzing space systems some of their peculiarities surface. One such peculiarity is that of their evolving repair scenarios. Figure 4 depicts the anticipated tendencies with regard to who or what accomplishes the repair:

Repairs currently performed by human technicians will be transferred to robotics, and eventually the software, to a large degree, will be "self-repair" (which is facilitated by reusable

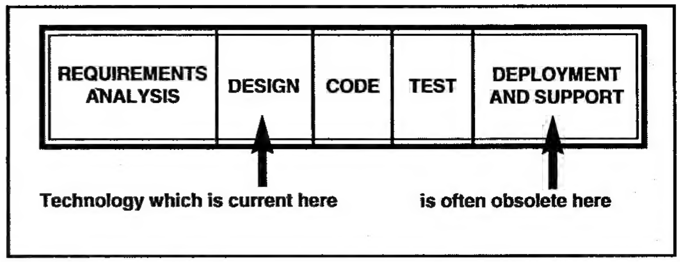

Figure 3. Computer Hardware and Software Technology and Systems Design Timeline.

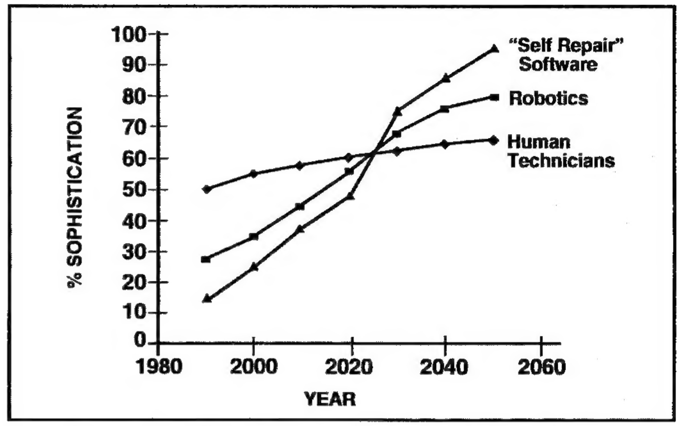

Figure 4. Anticipated Tendencies of Space Systems Repair Sophistication.

software and modularity). This will allow on-board personnel to focus their efforts on the primary mission of the space system.

The primary mission of the Space Station *Freedom* is to provide supporting functions and operations to multiple users. These functions and operations provide a capability for:

(1) Materials processing research.

(2) Life sciences research including permanently manned presence and a permanent observatory.

Space Station LSA

The LSA effort for the space station program consists of modular development. The space station Program Requirements Document (PRD) identifies the LSA program as encompassing the traditional definitions, plus the LSA will be performed throughout the program life-cycle for future modifications and evolutionary growth.

	RELIABILITY	MAINTAINABILITY
Hardware	Probability that a system or product will perform its intended function under defined conditions at designated times for specified operating periods.	Inherent characteristic of a design or installation that determines the ease, economy, safety, and accuracy with which maintenance actions can be performed.
Software	Probability of failure-free operation of a computer program in a specified environment for a specified time.	Ease at which software can be understood, corrected, adapted, and/or enhanced.

Table 2. Hardware Versus Software Reliability and Maintainability.

Some of the concerns and issues that were considered for Space Station *Freedom,* and need to be considered for all space systems, are:

(1) Maintenance Requirements.
(2) Robotic Tasks.
(3) Extravehicular Activity Tasks.
(4) Intravehicular Activity Servicing.
(5) Design Redundancy.
(6) Human/Environmental Concerns.
(7) Transport/Packaging Concerns.

Maintenance Requirements

Due to the strict crew time resource constraints inherent with on-orbit operations, it was necessary to develop maintenance philosophies that would ensure maximum maintainability of the space station. This resulted in the identification of the Orbital Replaceable Unit (ORU). The ORU is defined as that level of hardware that can be removed and replaced on-location under orbital conditions. Employing standard design and analysis criteria, ORU requirements regarding removal and replacement, accessibility, alignment, mounting, and criticality were determined. Requirements were directed at assemblies needing periodic access to support servicing and corrective and preventive maintenance.

Some ORUs would have a minor impact on the crew time resource due to an extremely low failure occurrence; however, the impact on packaging design could be monumental. Many of these particular items are located in standoff locations and would not comply with access requirements. The question would normally be, "Since these items have such a low failure probability, can we ignore them?" The answer is no! The reason is space systems must consider meteoroid penetration. This cannot be predicted with any real accuracy; however, a meteoroid penetration at some point may result in damage requiring these items to be replaced or repaired.

It should be noted that the *Hubble* telescope was one program that paid serious attention to support of a space system and not be a "ship, shoot, and forget" piece of hardware. The *Hubble* was designed and built to be serviced in space. This can be easily seen as *Hubble* has two grapple fixtures that can be snared by the shuttle's robot arm, handrails that space walkers can use to maneuver and transgress the telescope, notches where small work platforms can be attached, and places where space walkers can fasten safety tethers.

Maintenance Tasks. Due to the hazardous materials and chemicals that are prevalent in space systems, it is imperative that warnings, cautions, or notes be heeded where an item is going from one environment to another. An object can go from being no problem to becoming deadly. For example, an astronaut in a space suit is protected from the effects of hazardous chemicals; however, if the astronaut handles an ORU containing a hazardous chemical, the astronaut must decontaminate the space suit prior to reentering the station. Failure to do so could cause death or injury to personnel. The EVA task or task performed outside the station would identify this warning.

Maintenance Levels. Because of the hazardous environment and unique systems being designed and developed for the space station, it was necessary to modify or add to the traditional maintenance levels (Table 3).

Flight Maintenance Information. Due to size constraint, location, transportation vehicle, manifest determination, etc., new requirements for maintenance data and training surfaced. The many volumes of text and drawings necessary to support the station could not possibly remain on-board; therefore, it was necessary to expand or come up with a more practical delivery system. A good candidate would be long distance maintenance and training. The completion of on-board maintenance will be supported by ground-based maintenance databases. Within this scenario, operational flight software displays will uplink maintenance information. Test and calibration of equipment will be conducted through the execution of uplinked maintenance procedures. An important point, however, is with regard to safety. During maintenance, the crew of the Space Station *Freedom* must always possess the capability to override or interrupt automated maintenance activities when confronted with personnel/equipment safety considerations.

CODE	MAINTENANCE LEVEL
O	Organization/Ground (Resupply/Return)
C	Organization/On Orbit (Responsibility of the Crew) - Inspect, Lubricate, Replace Parts, Repair Minor Assemblies
H	Intermediate/On Orbit - Calibration, Repair/Replacement of nonserviceable parts on orbit: (1) Penetration of an Orbital Replacement Unit (ORU) envelope and/or (2) Removal of an item from its next higher assembly to perform maintenance
F	Intermediate Ground
D	Depot
G	Robotics - All tasks which are performed by robots - excludes all human tasks
L	Extravehicular Activity - Those tasks which are performed external of the Space Station - excluding Robotic tasks

Table 3. Modified or New Maintenance Levels.

Robotic Tasks

Due to the ever-present life threatening environment outside the station, robotic tasks will be used where practical and cost effective. Markings and lights need to be provided to support computer vision and other vision requirements. The plan is for evolving space station design to incorporate increased utilization of autonomous robotic devices.

ORUs installed in non-pressurized areas will be designed to be removed and replaced by robotic/telerobotic means. Robotics will be operated from control areas within the pressurized environments.

Extravehicular Activity (EVA) Tasks

Pressurized logistics elements will not be exchanged by EVA activity. Part of the design is to include provisions for use of EVA as a backup to robotic activity.

EVA tasks carry restrictions that differ from earth-based (including aircraft) systems:

- There is limited time available for conducting EVA tasks.
- There is always the potential of being struck by a meteoroid or other types of debris.
- Payloads/free flyers have a design requirement to meet a 0.99865 probability that exposure to meteoroid/debris environment does not endanger the crew or space station survivability.

With regards to the space station core equipment, there are two basic types of categories:

(1) *Critical Category:* This is comprised of equipment whose failure or secondary effects of that failure will endanger the crew or space station survivability.

(2) *Functional Category:* This category is composed of those pieces of equipment whose failure may degrade the space station's performance but does not endanger the crew or space station survivability.

Intravehicular Activity (IVA) Servicing

This effort provides for planning, scheduling, control, and monitoring of servicing activities. It provides for limited repair of ORUs either in centralized or distributed areas throughout the pressurized modules. Control stations within the pressurized environments allow for the operation of the space station robotics.

The servicing allows for the limited monitoring of external servicing activities on the space station via direct observation or closed circuit television (CCTV).

Design Redundancy

Another design consideration of the space station hardware is system redundancy. The redundancy is to permit verification of operational capability (the ability to perform the intended function) without removal of ORUs. During the space station manned-base phase of the Space Station *Freedom* program, systems whose failures are time critical/life threatening need to possess automatically activated redundancy. The design must ensure that no single control instrumentation failure causes loss of more than one functionally redundant path.

It needs to be pointed out that with traditional LSA, it is okay if the test environment is not 100% like the actual one. It is possible to simulate something close, and once the system went into the field, adjustments could conceivably be made. A recent space system became unusable due perhaps to the lack of experience with the actual operating environment.

The Mars Observer traveled 442 million miles and was three days short of entering Mars' orbit when communication with it was lost. It is thought that a broken fuel line is the culprit. The plumbing system was "tested" in earth's orbit, which is relatively warm as compared to traveling through deep space. The effects of extreme cold for an extended period of time was not adequately considered in making a decision to pressurize. The result was loss of communication.

Human/Environmental Concerns

Safe Haven Capabilities. In order to ensure crew survival, in case of any single failure (including the complete loss of any one pressurized element), provision must be made for a safe haven. Safe haven resources, provisions, and capabilities need to be sized for a maximum duration. In case a safe haven condition occurs while conducting an EVA, there needs to be a provision for assuring EVA crew reentry. Safe haven capability needs to last for the life of the space station (or any manned space system), beginning when the station is initially manned on a permanent basis.

Safe Emergency Egress. The space station design will include safe emergency IVA egress in the event crew evacuation from any pressurized element to the remaining continuous pressurized volume is required. Safe emergency egress time cannot exceed three minutes, including time required to secure hatch(es).

Transport/Packaging Concerns

This area is one of major concern. When supplies are needed, a simple call for overnight delivery is not possible. The National Space Transportation System (NSTS) is complex in nature and has unique requirements of its own.

Supplies are transported in the orbiter's cargo bay. The orbiter's cargo bay is comprised of an area 60 feet long and 15 feet in diameter. The shipping manifests are determined years ahead for any particular flight. Some space is taken up for possibly a payload, replacement ORUs, components, and resupply operations. It becomes very clear the major impact an "unplanned for or unscheduled" flight would have.

The limited number of vehicles, cost associated with preparing and executing a launch, weather conditions at the launch site, and physical condition of the launch vehicle represent some of the variables that may or may not cause a delay in providing needed parts/supplies to orbiting space systems.

Future of LSA

What do we need to do to effectively support our high technology space systems? We need to start changing the way we view LSA and look at the problems we have encountered and will encounter with the Space Station *Freedom* program. For the high technology "leading edge" programs, it is time to start approaching LSA from a nontraditional angle. The traditional LSA is based upon a hardware-oriented viewpoint. Everyday it can be seen, however, that software plays an increasingly vital function in the development, upgrade, and continuing support of the newer systems. It is time to incorporate software requirements into the 1388 series MIL-STDs (LSA/LSAR).

The type of environment that space systems and platforms will inhabit introduces many concerns—transportation, human factors, maintenance, meteoroid penetration—to name a few, that need to be identified and incorporated into the MIL-STDs. Or perhaps, new "Space Standards" need to be created.

The ultimate goal is for all EVA tasks to be performed by robots. Until that time, humans need to journey outside the space craft into probably the most dangerous and unfriendly environment known to man and assist robots in performing necessary tasks.

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From R&D to Operations: Launch Vehicle Logistics

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Introduction

Prior to the mid-1970s, the Air Force relied primarily on expendable launch vehicles (ELVs) for placing satellites in orbit. From the mid-1970s to the *Challenger* disaster in 1986, national policy resulted in the Air Force using the shuttle as its primary launch vehicle. Because most payloads were delivered by the shuttle, minimal consideration had been given to the care and upkeep of ELV launch complexes and ground support equipment. Most of that equipment at Cape Canaveral had been owned and operated by National Aeronautics and Space Administration (NASA). After *Challenger*, the Air Force was faced with a growing backlog of launch needs.

To satisfy medium launch needs, the Air Force acquired most of the old launch complexes and equipment at Cape Canaveral Air Force Station (CCAFS) and commercially contracted for launch services. The extent of government involvement in medium launch has been to provide the contractor facilities, ground support equipment, and general oversight of launch operations. The government owns approximately 90% of the equipment and is responsible for its care and upkeep.

Over the decades of vehicle evolution, logistics support was provided on an as-needed basis. Typically, the launch contractor was tasked to provide the support it deemed necessary. There was no strategic plan for launch vehicle logistics.

Logistic support is provided by prime contractors and a host of base support contractors. This situation is a result of the evolution of those vehicles over several decades of research and development-like programs. Because launch contracts typically purchase only a handful of launches, modifications were not based on a long-term vision of developing competitive, efficient US launch capability. To minimize the risk of launch failure and ensure the contractor had full launch responsibility, contracts were firm fixed price for the entire operation. The government has few opportunities to save significant dollars or to dramatically change the face of launch.

Today, the Air Force is examining opportunities to apply standard logistics systems and practices to ELVs, referred to as "normalization," thereby improving the operational performance and costs of the ELVs for the next decade and laying the logistics groundwork for future ELVs.

This paper describes the evaluation of logistics alternatives for the Medium Launch Vehicle (MLV) III program, whose primary function is launching Global Positioning System satellites. The MLV III contract was awarded to McDonnell Douglas Aerospace (MDA) and its Delta II launch vehicle in April 1993. The basic contract calls for 24 launches over six years; options provide for up to 12 additional launches. All launches will occur at Cape Canaveral Air Force Station. Because of the number of launches, MLV III provides a major opportunity for considering logistics options.

Delta II Logistics Today

Currently, logistic support is provided by MDA and several base support contractors; the Air Force role is limited to oversight of contractor operations. MDA, as the launch contractor, has total system performance responsibility. In the logistics arena, MDA does the following:

- Provides all spares for both flight and ground hardware.
- Provides personnel and training.
- Maintains all ground equipment (support equipment and mission equipment).
- Maintains technical data.

All levels of maintenance on ground equipment are performed at CCAFS. Flight equipment spares are obtained primarily from the Delta II production line; only a small number of flight parts are stocked at the launch site. Spares for ground equipment are purchased by MDA from a variety of vendors. Base support contractors provide propellants and maintain facilities and major installed equipment, such as hoists, elevators, and large air conditioners.

Several key characteristics of launch have a bearing on logistics normalization. The very high reliability requirement, which is associated with the high dollar value of the vehicle and payload, demands that changes to support do nothing to increase launch risk. Delays in launch processing, which depends on ground equipment, can be costly, so support must be responsive. Because the Delta II is used for DOD, NASA, and commercial launches, changes to the logistics system must not impair the support given to any of those customers.

Logistics Options and Scenarios

To allow for normalization of logistics, the MLV III contract contains a number of priced and unpriced options for logistics (Table 1). Those options address base supply, provisioning, support equipment management, maintenance data collection, technical information, and training. Both the launch vehicle system (LVS) and the launch base complex (LBC) are included.

Under the current launch scenario, the launch vehicle contractor has total system performance responsibility and the Air Force provides oversight. Other operational scenarios are possible: the Air Force could assume some functions now performed by the contractor, such as launch pad refurbishment, launch operations, vehicle assembly and checkout on the launch pad, and processing of vehicle components. The desirability of some logistics options is affected by the operational scenario.

Measures of Merit

The goal of normalizing various aspects of launch vehicle logistics is analyzed in terms of the associated costs and performance impacts. Comparison of logistic support alternatives is based on the following measures that relate the

Priced Options
Launch Base Complex Support Equipment Recommendation Data
Launch Base Complex Provisioning Process
Standard Base Supply System and Standard Data Systems
Launch Base Complex Technical Data
Launch Vehicle System Support Equipment Recommendation Data
Launch Vehicle System Provisioning Process
Unpriced Options
Support System
Spares Consignment
Launch Base Complex Technical Manuals and Procedures
Training Infrastructure
Organic Depot Infrastructure
Vehicle Storage

Table 1. Logistics Options in the Medium Launch Vehicle III Contract.

distinguishing characteristics of the alternatives to the overall concerns:

(1) Life cycle cost.
(2) Schedule (including responsiveness).
(3) Operational knowledge.
(4) Impact on non-DOD launches.

Life cycle cost is an obvious consideration. Launch schedules are another clear concern. Because logistics factors have not been significant causes of Delta II launch delays, the measure focuses on avoiding degradation of the schedule and reducing variation in the time required to respond to support needs. Improved operational knowledge would be useful to the Air Force in the baseline scenario, as it would provide visibility into status and problems and would promote improved management of the ground assets. Furthermore, it would be critical in scenarios where the Air Force assumes responsibility for portions of launch vehicle processing. Impact on non-DOD launches is included as a measure because the Delta II is used for commercial and NASA launches. Those launches should not become more costly or lengthy because of changes to Air Force logistic support practices.

The time horizon for the costs and benefits associated with the logistic support alternatives extends beyond the MLV III program. This horizon is used because some alternatives were conceived as long-term changes in how the Air Force operates expendable launch vehicles.

Analysis of Options

The major logistics options are in the areas of supply and ground equipment management. Supply, in turn, has implications for provisioning data and maintenance data. Ground equipment management requires some support equipment recommendation data (SERDs) as well as maintenance data. The areas of technical information and training are also recognized as logistics options.

Supply

The use of the standard base supply system (SBSS) for Delta II supply operations has the potential to reduce costs while maintaining responsiveness. Benefits of SBSS include:

- Automated demand analysis.
- Reduced inventory requirements due to improved demand knowledge and sharing of stock.
- Lower overhead costs for local purchases.
- Centralized computer support (which reduces the proliferation of unique, local computer systems).

In addition, using standard procedures and knowledge gained through data collection gives the government a credible option to compete the supply services.

Several aspects of supply for a launch vehicle system require special consideration. Most importantly, because some ground equipment is used on the critical path for vehicle processing and launch, support must be highly responsive. Some parts required for Delta II ground equipment are not used elsewhere in the Air Force. Such specialized usage limits the opportunity for volume purchases.

MDA operates a supply facility located about one mile from the launch pad. The seven-person staff supports both flight and ground hardware for both government and commercial launches. The bench stock inventory lists about 11,000 government items, of which about 75% are stocked. Many parts for the ground equipment are not stocked but are procured by the supply group. A typical year has about 1,000 transactions involving about $500,000 of material.

We have identified several features of the MDA supply operation at CCAFS that appear to be essential to success under the current conditions. Similar features are found at the 89th Support Squadron at Andrews AFB, Maryland, which has the analogous problem of providing support for old, unique VIP aircraft that have high reliability and availability requirements. These features are:

- Relatively large inventory of parts required to support old equipment.
- Supply demand determination performed locally at CCAFS (CCAFS is essentially the only Delta operating location).
- Responsive procurement capability maintained on-site (much of the equipment either is not stocklisted (no NSN) or is stocklisted but not stocked by a depot).
- Higher than normal technical quality inspection of incoming parts and supplies due to uncertainties of launch and the consequences of failure.
- Large supply of raw materials, piece parts, and bench stock maintained (most intermediate and depot-level maintenance is performed on Delta II support equipment at CCAFS due to equipment age and uniqueness).

In the long term, SBSS, along with an effective maintenance data collection system, may potentially reduce the need for large inventories, local demand analysis, local procurement capability, and local intermediate and depot maintenance. In the near term, SBSS must provide the features identified above. Stringent quality control will remain the user's responsibility.

There are some useful actions that can be taken now to begin the normalization process. The first is the installation of an SBSS terminal at the MDA supply point. The second is the assignment of a government supply sergeant or civil servant equipped with an International Merchant Purchase Authorization Card (IMPAC) and Military Standard Requisitioning and Issue Procedures (MILSTRIP) authority to work with the MDA personnel at the supply point. That individual can directly support current supply activities with his procurement capability, and can begin the process of examining the inventory to determine cataloging and stockage requirements. Of course, that supply support must be provided for both government and commercial launches.

In the longer term, the government agent will support the cataloging of the parts identified by the maintenance task analysis and provisioning process. That individual will also be

responsible for securing the necessary priorities and service from the Air Force and Defense Logistics Agency (DLA) supply systems.

The immediate benefit of the near-term actions will be the increase in data to base supply on usage rates. This will be achieved through the use of the IMPAC card to procure essentially all of the items now locally purchased by MDA. Data from IMPAC card procurements would be logged and tracked by base supply to develop stockage requirements.

The long-term benefits depend on extension of the Delta normalization to the rest of the launch vehicles. Currently, individual independent supply inventories are maintained for each launch vehicle. When common equipment is identified, cataloged, and stocked, then reductions in the individual inventories can be made without hindering operations and maintenance.

Provisioning

The MLV III contract includes an option for the provisioning process. That process is normally used to identify the initial spares and the stockage points. The hardware is identified by National Stock Number (NSN), and the stockage location is identified by Source, Maintenance, and Recoverability (SMR) code. Supplementary Provisioning Technical Documentation (SPTD) consists of drawings, standards, and other detailed technical data necessary to repair, remanufacture, or reprocure the item.

The MLV III contract is unusual because it predominantly covers hardware that is already fielded, maintained, and supplied. Stockage and maintenance levels are already established. Some new equipment is being purchased, but the maintenance approach for those new items is already defined. On the surface, the fundamental purposes for the provisioning process do not appear to exist for the MLV III.

However, because usage data has not been collected, the provisioning data is needed for timely implementation of standardized supply. In addition, those data may support standardization of launch support equipment, depot item management, organic, or competed maintenance and operations. Identification of the correct SPTD is completely dependent on knowledge of the work it is required to support. To correctly identify the SPTD needed for normalization, maintenance tasks must be analyzed to identify how the maintenance will be accomplished, what equipment and parts will be necessary, and who will perform the maintenance.

Ground Equipment Management

Approximately 2,600 items of ground equipment are used to process the Delta II at CCAFS. That equipment includes support equipment (SE), common tools, and installed equipment (such as hoists, elevators, and air conditioners). Several hundred items of the SE are unique to the Delta II. However, most of the major components (line replaceable units) of those SE are not unique.

Almost all of the ground equipment is owned by the government. All corrective and preventive maintenance is performed by contractors. Much of the ground equipment is old: over half of the items are at least 20 years old. As might be expected, ground equipment has a high maintenance burden. For example, almost 20% of the MDA staff at CCAFS are assigned to preventive maintenance of ground equipment.

Because of the historical evolution of launch capabilities, there is no planned approach to managing the ground equipment. We suggest a two-part approach to improve support and management of the ground equipment. The first part focuses on supply support (see the above section). The second part deals with equipment replacement and entails the following activities:

(1) Collect maintenance data on the ground equipment to identify the major consumers of support resources (labor, calendar time, and parts). Those data can form the foundation of an equipment replacement program. The Air Force and its contractors should periodically review the maintenance data to identify specific equipment that warrants replacement to improve reliability, reduce launch support cost, and reduce risks to the launch vehicle processing schedule.

(2) For equipment that is known to have a high support burden, or that is old and likely to need replacement in the near future, develop the support equipment recommendation data (SERDs). The SERD contains a functional description of the equipment and is needed for acquiring replacement equipment.

(3) For ground equipment that is not expected to be replaced for some time, obtain the provisioning data. This step will enhance application of the standard Air Force supply system, which has the potential to reduce parts costs and, over the long term, to promote standardization of equipment.

Maintenance Data Collection

Maintenance data are needed to identify the major consumers of maintenance resources and trends in equipment problems. Under current operations, insufficient maintenance data are collected to fully support those needs. For instance, data to economically justify replacement of equipment are not collected.

One of the logistics options is for maintenance data collection (MDC) using the Core Automated Maintenance System (CAMS). CAMS, a standard Air Force MDC system, was originally developed for aircraft. Today it has capabilities for support equipment. While the capabilities of CAMS are more extensive than needed, CAMS provides an economical means of implementing MDC. Installation will cost less than $40,000 and will require about 4 to 6 terminals (personal computers), basic communications hardware, and software. Using the CAMS interface with the Air Force's Reliability & Maintainability Management Information System (REMIS), allows storage of all historical data and enables Air Force-wide analysis of equipment. Use of a standard Air Force system will save on software costs and ensure that the data are in formats familiar to Air Force personnel. In addition, CAMS has an interface with the SBSS so parts can be ordered when maintenance data are recorded.

MDC implementation should be evolutionary because the effort of data collection will not be worthwhile for all ground equipment. The initial items for MDC can be identified using the experience of the Delta II work force. Additional items can be added as dictated by additional experience. Data collection should begin at the equipment level. For some of the more complex, higher cost items, such as the ordnance test set, it may be useful to consider collecting maintenance data for selected subsystems.

MDC data will provide a basis for economic modernization of ground equipment with high support costs, as well as visibility into the status of key processing equipment.

Technical Information

The basic MLV III contract establishes a technical library of launch vehicle processing documents, drawings, and technical manuals. While those data are not in standard Air Force formats, they are sufficient for the current oversight responsibility.

If the Air Force assumes responsibility for portions of Delta II processing, then it should acquire the associated technical data. Furthermore, either the launch processing documents need to be converted to standard technical orders (format and level of

detail) or the assigned personnel must receive sufficient training to enable them to use the current documents.

Training

One of the unpriced options in the MLV III contract is to provide a training infrastructure. This option is needed if the Air Force chooses to assume responsibility for some portions of launch vehicle processing. The infrastructure should be targeted for the skills needed in the those portions.

Summary

Our study of logistics options for the ML III contract showed that several logistics normalization steps should be implemented in the baseline scenario.

Standard base supply, with tailoring to ensure responsiveness, should be applied to ground equipment. Acquisition of selected provisioning data will enhance that application. The supply-related options will cost about $1.4 million and save about $2.0 million over the MLV III program. Support equipment recommendation data should be acquired for equipment that is likely to be replaced during the life of the contract. Maintenance data should be collected to provide insights into the major consumers of support resources and to provide a basis for improved management of the ground equipment. Implementing the associated options will cost about $1.1 million. Replacing $5 million of aged support equipment raises the investment to $6.1 million. The expected saving are about $7.1 million.

If the Air Force chooses an operational scenario in which it takes over some of the vehicle processing, then additional options to procure associated technical data and training infrastructure must be exercised. Those options could cost from $6 million to $40 million, depending on the extent of the Air Force's role.

Future Considerations for ELV Logistics Support

Although our work focused on the Delta II vehicle for the MLV III contract, our discussion and analysis indicate several areas for broader consideration of logistics options. Three of those areas have commonality as a theme. First, some support equipment may be common across different launch vehicles. If this is so, then economies of scale might be achieved through common or shared management and support of that equipment by the Air Force and/or NASA launch programs. Second, although the same propellants are used in multiple vehicles, each vehicle has its own propellant delivery system. Consideration should be given to migrating to a common delivery system, which would reduce the total amount of equipment needed. The third area is oriented toward Air Force organization. The current approach is to dedicate a squadron to each vehicle. A mechanism for sharing insights and approaches across vehicles could lead to efficiencies.

Finally, we must point out the limitations of trying to reduce the logistics burdens of the current ELVs. The logistics burdens are heavily dependent on the design of the vehicle. Such factors as the use of a variety of liquid propellants, vertical assembly at the launch pad, and limited test points and access doors limit the opportunities for savings. As demonstrated by the Delta Clipper* and several foreign vehicles, it is possible to design a vehicle that takes significantly less resources to support than our current ELVs. Nevertheless, as our study has demonstrated, there are some opportunities within logistics to migrate our launch vehicles to an environment that is more operational than R&D-like.

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* The Delta Clipper is an experimental scale-model vertical takeoff and landing single-stage-to-orbit vehicle.

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The growth trend for the repair scenario on space systems is more toward robots and self-repairing software. The space station's purpose is for materials research and life sciences research. It is not the intent of on-board personnel to deviate from this and spend long hours effecting repairs. Therefore, design and supportability requirements identification via LSA need to keep pace with the rapidly changing advances in technology. This realization is just starting to surface on the space station program and will continue to do so on other space programs.

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The original version of this article appeared in the 29th Annual International Logistics Symposium Technical Proceedings of the Society of Logistics Engineers (1994).

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Current Research

Air Force Materiel Command (AFMC) Management Sciences Study Program

The HQ AFMC Management Sciences Division (HQ AFMC/XPS) is responsible for developing, managing, and executing Headquarters Air Force Materiel Command's management sciences program. We have focused our efforts in the development and enhancement of mathematical models that can relate materiel resource decisions to impacts on weapon system availability so AFMC can prioritize and justify its investments in resources. We work closely with our customers as we design and perform studies to ensure we have a healthy balance between the rigorous application of operations research techniques and practical solutions that can be implemented.

The XPS senior staff consists of:

Mr Victor J. Presutti, Jr., Chief, DSN 787-3201

Mr Curtis E. Neumann, Analytic Applications Function, DSN 787-6920

Mr Paul Frank, Concept Development Function, DSN 787-7408

The following is a partial list of current/recent XPS efforts:

Weapon System Program Assessment Review (WSPAR) Modeling Assistance and Technical Support. A WSPAR is a high-level briefing on the health of a weapon system. Current capability is shown relative to the planned operational requirement. Problems with weapon system support are discussed, along with proposed solutions, and forecasts of future peacetime and wartime capability (given budgets and logistics support) are presented. System Program Directors (SPDs) prepare WSPAR capability projections by using the Windows Integrated Logistics Assessment Model (WINLAM). These projections are a mathematical representation of the relationships among mission capable rates, spares and maintenance funding, support policies, and several other factors. In the past, we have supported the WINLAM developers by evaluating the modeling methodology and testing the software. As more SPDs have begun applying the product, our focus has shifted to the using organizations. We are explaining how the model can be used, describing its limitations, and addressing problems. Having resident expertise enables us to provide rapid technical assistance. (Analysts: Mike Niklas, Fred Rexroad, Tom Stafford, DSN 787-6920)

Distribution and Repair in Variable Environments (DRIVE). Our 1994 DRIVE work continued the theme of integrating DRIVE into logistics processes. Our efforts concentrated on automating DRIVE distribution, setting base levels, relating DRIVE to Lean Logistics, and enhancing the DRIVE Production System. We assisted in designing, implementing, and testing the DRIVE Distribution Module (DDM) at Ogden, Oklahoma City, and Warner-Robins Air Logistics Centers (ALCs). DDM is a system composed of DeskTop DRIVE married to an item manager emulator that accepts daily data feeds from the DRIVE production system mainframe computer. We also participated in using DRIVE to successfully set base stockage levels for the B-1B Operational Readiness Assessment (ORA). Our most significant DRIVE Production System enhancements were adding the capability to include all nonflying-hour-based as well as flying-hour-based aircraft exchangeable items and identifying a fix for a long-term in-transit data problem. The in-transit data fix benefited the requirements systems as well and avoided hundreds of hours of item manager file maintenance. Our 1995 efforts will concentrate on four areas—implementing automated DRIVE distribution operations, integrating an assessment capability with DRIVE, working towards a central level-setting capability, and integrating DRIVE capabilities into the Lean Logistics initiatives as appropriate. (Analysts: Bob McCormick, Barbara J. Wieland, Capt Christian Dussault, DSN 787-6920)

Joint Logistics Systems Center (JLSC) Support. Our office is a member of the JLSC "math models group" tasked in a joint DOD effort to devise common requirements models to be used by all the DOD components. We are being funded by the JLSC to look specifically in the area of multi-echelon, readiness based sparing (RBS) techniques. We are working to determine which of the RBS models available in DOD best computes Air Force Initial Requirements Determination (IRD). We are looking at the Navy's Aviation Retail Requirements Oriented to Weapon Replaceable Assemblies (ARROWs) algorithm and the Air Force's Aircraft Sustainability Model (ASM). Both will be analyzed as to which method best provides the desired functionality for a readiness-based IRD system. Other areas where we are focusing our efforts include testing a "standardized" wholesale Economic Order Quantity (EOQ) model. This testing will include the analysis of the proper parameter settings (ordering cost, maximum acceptable probability of stockout, etc.) required by the Air Force for a consumable item requirements computation. The final area of analysis will look at Air Force consumable line replaceable units (LRUs), those items traditionally computed under an EOQ computation. However, these items also directly impact the availability of a weapon system. We are going to look at the extent of these items and determine if a better approach exists for their requirements computation. (Analyst: Bill Morgan, DSN 787-6920)

Analysis of C-17 Engine and Module Maintenance Locations. The objective of this effort is to provide the C-17 System Program Office (SPO) an evaluation of maintenance concept and location options for the C-17 engine and modules. The study involved two program sizes: 110 program authorized aircraft (PAA) and 40 PAA. The maintenance options for the 110 PAA are: (1) organic depot repair with two Air Mobility Command (AMC) module replacement centers (MRCs), (2) organic depot repair with one AMC MRC and one MRC collocated with the depot, (3) organic depot repair with one MRC collocated at the depot, (4) contractor logistics support (CLS) repair with two AMC MRCs, (5) CLS repair with one MRC collocated with the depot, and (6) CLS repair with no MRCs (100% not repairable this station (NRTS)). The maintenance options for the 40 PAA are: (1) organic depot repair with one AMC MRC, (2) organic depot repair with one MRC collocated with the depot, (3) CLS repair with one AMC MRC, (4) CLS repair with one MRC collocated with the depot, and (5) CLS repair with no MRCs (100% NRTS). Our study compared the options by forcing equal aircraft availability across options during surge and sustained periods of war by adjusting engine and module spares levels, then comparing the costs of resources to obtain the given availabilities. Our results show the **best maintenance options**

for the 110 PAA are either the organic or CLS depot with two AMC MRCs. The best options for the 40 PAA are either the organic or CLS depot with one AMC MRC. Further analysis is required to determine whether the organic or the CLS maintenance alternative is the best. (Analysts: Harold Hixson, Tom Stafford, DSN 787-7408)

RSD Banding for Effectiveness. In today's environment of funding limitations, "banding" has gone from a fire-fighting stopgap measure to a way of life for distributing Obligation Authority (OA). This year the banding process was refined to avoid some problems that occurred the first year. One of the major improvements was the use of a different data source which helped ensure that all reparable spare items made it into the computation for funding consideration. Another "major" improvement was the increase in communication among the Air Logistic Centers and the Headquarters this year. While our communication is still below a desired level, it has improved tremendously. In the end, we produced a weapon system/ALC funding breakout which optimally spread from $550+M to $800+M Obligation Authority, given our normalized requirement for $1.063 billion. In addition we supplied a shopping list which gave the Item Managers a starting point for spending the allocated OA. (Analysts: Fred Rexroad, 1Lt Rob Block, Bill Morgan, DSN 787-6920)

Logistics Enhancement Awareness Development (LEAD). LEAD is designed to provide senior officers with basic knowledge about, and the feel for, the role of operational logistics in wartime situations. The objective is to enhance the logistics awareness that senior officers need for sound planning and decision making while making only modest demands on their schedule. During 1994, the 12AF (ACC), the 15AF (AMC), and the 21AF (AMC) participated in LEAD seminars chaired by their respective commanders. The Air Force Wargaming Institute hosted a LEAD workshop for Air Command and Staff College (ACSC) faculty and graduating students. As a result of this workshop, additional LEAD seminars are being planned for the ACSC curriculum. Based on the positive feedback from the seminar participants, the LEAD contract, through KAPOS and Associates, was extended into a second year with an option remaining for a third year. At the beginning of the second year of the contract, project responsibility transitioned from HQ AFMC/XPS to HQ AFMC/XP-AO. (Analyst: Mr Thomas Stafford, DSN 787-7408)

Lean Logistics Support. Lean Logistics is an Air Force initiative to speed up the repair, procurement, and transportation processes to provide better support to the end users at the lowest possible cost. All process improvements developed under the two-level maintenance initiative will be incorporated or further developed under Lean Logistics. Our office has supported Lean Logistics in a number of ways. We participated on a team that used theory of constraints (TOC) tools on the reparable portion of the logistics process to identify core problems and to propose potential solutions. We have used the Aircraft Availability Model (AAM) to test the effects of shortening resupply times on the peacetime spares requirements computation. One of the ideas for reducing resupply times under Lean Logistics involves a buffer stock concept that pulls much of the peacetime stock back from the bases into a centralized buffer with very fast transportation back to the bases as needed. This stockage buffer, which is presently called the Consolidated Serviceable Inventory (CSI), would both supply the base users and act as a controlling mechanism for depot repair activities. We have begun a project to explore impacts on aircraft availability using this CSI concept. We are working on an analysis that relates required repair capacity to repair prioritization alternative. (Analysts: Bob McCormick, Barbara Wieland, DSN 787-6920)

Peacetime Assessment Model for Non-Aircraft Command, Control, Communication, Computer and Intelligence (C4I) items. We are developing a prototype peacetime assessment model for non-aircraft C4I reparable items based on item specific requirements and funding. We are currently creating an algorithm to build indenture level information based upon D041 (Recoverable Consumption Item Requirements System) data. We will be able to show the requirement and the "availability" of each depot-level reparable (DLR) end-item. This will create a predictive assessment model to assist C4I System Program Directors (SPDs) in evaluating and managing their weapon systems. (Analysts: 1Lt Rob Block, Fred Rexroad, Jean Graham, DSN 787-6920)

Workload Projection and Manpower Planning. We are initiating an effort to see if we can assist our colleagues in the manpower and logistics communities to better forecast workload and the manning required to accomplish the workload. (Analysts: Freddie Riggins, Don Casey, Barbara Wieland, DSN 787-7408)

Space Shuttle Program Integrated Logistics Panel

Leroy J. Graham

This paper addresses the reactivation, implementation, and operation of the Space Shuttle Program's Integrated Logistics Panel (ILP) for the National Space Transportation System (NSTS). This management tool was reactivated after the shuttle disaster of January 26, 1986, when the orbiter *Challenger* was lost. This panel was reactivated to provide the Manager of the Space Shuttle Program and his management staff with the logistics posture of each of the project elements within the Space Shuttle Program on a regular basis. The panel brings together all of the shuttle program project element logistics representatives and gives each of them the opportunity to report their logistics and supportability status based on a pre-established agenda. Such areas as the NASA Shuttle Logistics Depot repair turn around times, status of inventory, problems encountered, and lessons learned are reported and discussed at this gathering of space logisticians. The results of the panel are reported to the Space Shuttle Program management for information and further action if necessary.

Introduction

After the *Challenger* disaster, the report issued by the Rogers' Commission (the president's commission on the *Challenger* disaster) addressed not only the solid rocket booster (SRB) design problems, but also the risk assessment and support problems which contributed to the disaster. As a result of this report, the Space Shuttle Program was directed to develop a logistics support system to fully support a reasonable flight rate for the remaining orbiters. The health of the Space Shuttle Program was reassessed and plans for a new reasonable mission flow was implemented. Managing such a flight program requires more than just adequate planning, it requires that management thoroughly understand the logistics management systems and be informed as to the health of the logistics posture throughout the program. To meet this requirement, the Integrated Logistics Panel was reactivated. To understand the panel function, it is necessary to understand the structure of the space shuttle's logistics program.

The Logistics Program

The Space Shuttle Program is made up of several project elements. Each of these project elements have a distinct and vital role in making the space shuttle functional and operational. Like in most large organizations, there is a set of documents that provide policy, guidance, and direction for the operation of the Space Shuttle Program. The two most significant documents are the National Space Transportation System (NSTS) Directive #58E, *NSTS Integrated Logistics Panel*, and NSTS 07700, Volume XII, *Integrated Logistics Requirements Document*. Directive #58E outlines the responsibilities and make up of the ILP. The *Integrated Logistics Requirements Document* establishes the program policy and logistics requirements for the Space Shuttle Program's project elements. This document further identifies the following logistics processes monitored by NASA:

- Maintenance (off-line).
- Training.
- Handling.
- Transportation.
- Storage.
- Supply Support Management.
- Technical Data.

Each of these processes are listed in its own section within the document. The document identifies the Space Shuttle Program's project elements and outlines the responsibilities of each. The projects elements are:.

- Orbiter, which includes the orbital maneuvering system
- Three Space Shuttle Main Engines (SSMEs) (installed in the orbiter).
- Expendable External Tank (ET).
- Two Solid Rocket Boosters (SRBs).
- Payload Integration.
- Launch and Landing Mission.
- Operations/Mission Control Center.
- Flight Crew Operations.

The Support Process

The support process required to prepare a shuttle for launch essentially involves supporting the "flow" process. The flow process, as it is known, usually includes:

(1) Deactivating and purging all orbiter systems after landing at either Edwards AFB, California, or Kennedy Space Center, Florida.

(2) Flying the orbiter back to Kennedy Space Center (piggy-back on a Boeing 747) in cases when it lands at Edwards AFB.

(3) Removing the main engines, auxiliary power units, orbital maneuvering system, payload handling equipment, experiments, and other systems at the Launch Processing Facility at Kennedy Space Center.

(4) Performing necessary maintenance including replacing failed line replaceable units (LRUs), thermal tiles and blankets, etc.

(5) Installing airframe and system modifications.

(6) Installing refurbished engines, auxiliary power units, the orbital maneuvering system, and other systems.

(7) Installing payload fixtures and horizontal payloads.

(8) Stacking the solid rocket boosters on a Mobile Launch Platform (MLP) in the Vehicle Assembly Building (VAB).

(9) Attaching the External Tank (ET) to the Solid Rocket Boosters (SRBs).

(10) Towing the orbiter to the VAB and lifting it into its vertical position to attach the SRBs and ET.

(11) Transporting the complete space shuttle to the launch pad by the MLP.

(12) Installing vertical payloads.

(13) Performing final inspection and fuel servicing in preparation for launch.

The Integrated Logistics Panel (ILP)

The basic purpose and responsibilities of the ILP are outlined in Directive #58E. This directive establishes the NSTS Integrated Logistics Panel as a mechanism to generate, collect, and integrate requirements associated with the logistics processes for the Space Shuttle Program.

The manager of the NSTS Ground Systems Engineering Office at the Lyndon B. Johnson Space Center, Houston, Texas, was responsible for the implementation of Directive #58E, and was the ILP chairman prior to the Space Shuttle Program office reorganization in 1992. This responsibility transferred to a Space Shuttle Program satellite office located at the Kennedy Space Center. The manager of that office, or his designated representative, is now the chairman of the ILP, and the Kennedy Space Center Chief of Logistics, or his designated representative, is the deputy chairman.

The ILP was reestablished to influence or direct project actions as an extension of the Ground Operations technical area and to review or prepare changes to NSTS 07700, Volume XII when needed. The ILP's scope encompasses those activities involving the development, implementation, and closed-loop accounting of the logistics processes previously identified. Specifically, the ILP is to derive, coordinate, and implement the integrated logistics requirements and activities which are essential to the Space Shuttle Program. Technical subpanels are one of the principal mechanisms by which the ILP assures the accomplishment of these activities.

General

The panel and subpanel meetings are held on an "as required" basis, but usually semi-annually. The meeting dates and location are established by the chairman and provided to the members in sufficient time to prepare for the meeting. Agendas are established and provided to a predetermined list of presenters and interested parties. Minutes of the panel meeting are provided to all members within one week of completing the meeting. Action items worthy of program management attention are presented to the Space Shuttle Program Systems Integration Review Chairman for information and resolution.

Responsibilities

Chairman. The ILP chairman is responsible for:

(1) Accepting tasks/problems for panel action.

(2) Establishing time and location of panel meetings.

(3) Assigning action items to panel members.

(4) Monitoring status of action items to ensure completion.

(5) Publishing minutes of panel meetings.

(6) Establishing subpanels (as required) and appointing subpanel chairmen.

(7) Assigning tasks to subpanels.

(8) Receiving status reports/briefings on subpanel actions/progress.

(9) Integrating the efforts of the subpanels.

(10) Keeping program management informed of significant actions of the panel and subpanels.

(11) Referring problems/questions not resolvable by the panel to the Manager of the Space Shuttle Program.

Panel Member. Panel member responsibilities are to:

(1) Fully understand the logistics system and operations that are planned by their respective project elements.

(2) Establish requirements for standardization of the logistics activities of the project elements.

(3) Assess the technical adequacy of the logistics support posture for the operational program, such as conducting audits and reviews of each project element.

(4) Provide recommendations to program management to resolve logistics problems and to establish the most cost-effective approach.

(5) Review the status of activities of the various subpanels, keeping informed of major logistics technical problems and the impact on program schedules.

(6) Resolve technical issues referred to the panel from either program management or the various project element representatives.

(7) Address and resolve interface and system problems which exist between or extend beyond the scope of the subpanels.

(8) Define specific areas of technical responsibility describing general rules and procedures for the subpanels, including guidelines for membership, attendance, duration, etc.

Subpanel. Subpanels are responsible for:

(1) Resolving problems/questions assigned to them by the panel chairman or deputy chairman.

(2) Keeping the chairman informed of action or progress of the subpanel.

(3) Referring technical issues beyond the scope of the subpanel to the panel for action.

Panel Membership

Panel membership consists of representatives from the following functions:

- NASA Headquarters.
- National Space Transportation System Engineer Integration Office.
- Orbiter Project Office.
- National Space Transportation System Integration and Operations Office.
- External Tank Project Office.
- Space Shuttle Main Engines Project Office.
- Solid Rocket Booster Project Office.
- Director, Shuttle Logistics Project Management.
- Flight Crew Operations.
- Mission Operations/Mission Control Center.
- Western Space and Missile Center.

Summary

The Integrated Logistics Panel has been an effective management tool that provides the Space Shuttle Program with the synergism and interface needed to communicate logistics issues and concerns by all levels of logistics management. As quoted from the March 1992 annual report of the Aerospace Safety Advisory Panel, "The Integrated Logistics Panel series now provide an effective forum for interchange and communication upon the whole spectrum of logistics and support and especially upon the progress being made upon some of the potential show-stopping issues. The panel is pleased to observe the widening scope and energetic use of the Integrated Logistics Panel as a principal management tool."

The original version of this article appeared in the 29th Annual International Logistics Symposium Technical Proceedings of the Society of Logistics Engineers (1994).

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Improving Spacelift ReliabilityThrough Robust Design

Captain Sandra M. Gregory, USAF

Introduction

The Air Force relies extensively on expendable launch vehicles (ELVs) to place satellites into orbit. The ELV fleet currently includes Delta, Atlas, and Titan launch vehicles. These vehicles were originally designed over 30 years ago and are all derived, in varying degrees, from ballistic missile technology. (3:13) In fact, the Titan II is simply a refurbished intercontinental ballistic missile (ICBM). These ICBM technologies from the 1960s and 1970s are still being used today. (13:20)

The Titan II, Delta II, and Atlas are in the medium payload class based on the weight they can place into orbit, whereas the Titan IV is in the heavy payload class. To best explain the basic differences in the launch vehicles, and how those differences relate to reliability, the Delta II (referred to as Delta) and the Titan IV (referred to as Titan) will be considered in the most detail. The Atlas shares attributes of both the Delta and the Titan and usually its statistics fall between those of the other two ELVs.

Payload capacities to high earth orbit are 4,200 pounds to geostationary transfer orbit (GTO) for Delta, up to 8,450 pounds to GTO for Atlas, and up to 10,000 pounds to geosynchronous earth orbit (GEO) for Titan. (3:13) Flight rates also differ significantly, averaging three per year for Titan and less than four per year for Atlas, but averaging eight per year for Delta over the last fives. Due to the lower level of complexity, the Delta time on the launch pad is normally less than two months. Titan, on the other hand, is customized for each payload and normally requires almost four months to process on the launch pad. (3:13) Launch costs, reflecting the differences in the vehicles, are less than $100 million per flight for Delta and Atlas and more than $250 million per flight for Titan. (3:13)

Based on the *Space Launch Modernization Plan,* the product of the 1994 Moorman Study, the Air Force is currently pursuing the plan's option of evolving current expendable launch systems. Reliability, a characteristic of mission success, is a key requirement of any launch system. As the Air Force considers launch system modernization, we have the opportunity to use advances in designing-in-reliability concepts to ensure even greater reliability in the future.

This article addresses the failure and delay aspects of historical ELV reliability rates, presents the robust design concepts that have emerged since these ELVs were originally designed, and discusses reliability as a requirement for the new evolved expendable launch vehicle (EELV).

Historical Perspective

For the purpose of this article, mission success is defined as the probability of placing a satellite into orbit on schedule. Mission success is affected both by catastrophic failures that result in the complete loss of the launch vehicle and payload, and by launch delays. In the Air Force Space Command's *Draft Operational Requirements Document (ORD) for the EELV,* dated 31 March 1995, reliability is defined as "the ability of the spacelift system to successfully accomplish its intended mission." More specifically, to incorporate the on-time aspect of mission success, the *ORD* defines reliability (or dependability) of the schedule separately as "the ability of the system to consistently launch . . . when planned." In keeping with the *ORD,* this section will address both catastrophic failure and launch delay as aspects of the reliability characteristic of mission success.

Failures

Launch failures, or accidents, result in the loss of both the launch vehicle and the payload. A launch might also be considered a failure if the vehicle places the satellite into an orbit that is unusable for the purpose of the payload's intended mission. Even in this case, because the satellite cannot be used for its intended purpose and the vehicle cannot be restored, the dollar impact is the same as that incurred by an accident. (A failure of a satellite to operate properly after being placed into the proper orbit is not due to a fault in the launch vehicle and, therefore, would not be considered a launch failure; this type of failure is beyond the scope of this article.) Most failures are caused by propulsion systems rather than by avionics systems. (10)

ELV failures have cost an average of $300 million annually over the last 10 years and, with even higher launch vehicle and satellite price tags, will likely cost even more in the future. In addition, the lost opportunity cost of a standdown after an accident contributes to the high cost of launch failures. (3:7,26) Launch schedules slip and, depending on the length of the standdown, it may take many months to eliminate the backlog. Failure cost can be as much as half of the launch system's total life-cycle cost. (11:34)

Historical reliability (launch success) rates for the last 10 years are 98% for Delta (1 failure out of 50 launch attempts), 92.3% for Atlas (3 failures out of 39 attempts), and 87.5% for Titan (4 failures out of 32 attempts). See Table 2. The different launch success rates for the three launch vehicles can be attributed in part to their differences in complexity, flight rate, and design stability. For example, the high flight rates of the Delta have afforded a greater opportunity to identify and correct problems. Additionally, the higher flight rates result in higher production rates which help to improve system reliability. (3:11)

Launch Vehicle	Launch Success Rates (Last 10 Years)	Average (In Days)
Delta	98% 49/50	22
Atlas	92.3% 36/39	88
Titan	87.5% 28/32	223
Evolved Expendable Launch Vehicle Goal	98%	90% < 7

Table 1. Spacelift Reliability.

Due to the high cost of failure, extensive pre-launch testing is accomplished. Because the cost of failure for a Titan is much higher than for a Delta, Titan testing is even more extensive. Contractor engineers often become involved to correct problems encountered, contributing to the high cost of the current launch systems. Redundant testing is performed in the attempt to "make a 95% reliable booster 100% successful." (13:20) This pre-launch processing often contributes to launch delays. (6:2)

Delays

Launch delays are significant. The average delay for the Delta, Atlas, and Titan ELVs is 22, 88, and 223 days, respectively (Table 1). (3:10) The cost of a delay when the launch count has been initiated and all launch resources have been committed ranges from about $1 million per day for Delta to about $8 million per day for Titan. (13:20) Whenever problems are encountered during pre-launch processing, contractor engineers become involved to determine the causes and solutions. Therefore, a key portion of the delay cost is for this recurring engineer involvement. Because the Titan is customized for each payload, more of the manufacturing process extends to the launch pad. (3:10-11) Thus, the extent of engineering support is greater for Titan, contributing to the higher delay cost. Also, the larger and more expensive Titan payloads result in a larger standing army and a smaller tolerance for risk.

Delays have a number of causes. The following factors each account for over 10% of total delay time: upper stage (41%), payload (18%), booster (15%), and ground support equipment or facility (11%). Delays are frequently caused by the weather, but these delays are normally short (only 3% of total delay time). Payload-driven delays could be reduced by performing more payload processing off the launch pad. (14)

Robust Design Concepts

As stated earlier, today's ELVs were designed over 30 years ago. As performance needs increased over the years, the propulsion systems have been pushed to their performance limits. Very little, if any, of the original performance design margin remains. (10) Within the last decade, however, new design concepts have emerged that could be used to ensure adequate performance design margins and to improve reliability in new launch systems. These design concepts will be discussed next.

The generic design process consists of three steps: (1) system design, (2) parameter design, and (3) tolerance design. System design produces a functional design that may not be optimal in quality or cost. (9) Thus, reliability also would be suboptimal.

Parameter design results in the determination of optimal levels of controllable parameters so, in addition to being functional, the system will exhibit high performance under most conditions and will be insensitive, or robust, to noise factors. Noise factors are parameters that are either uncontrollable or prohibitively expensive to control. (9) The three sources of noise are the environment, deterioration, and manufacturing imperfections. (8:13)

The third step, tolerance design, is necessary if the parameter design results in a design that does not meet minimum performance specifications. Tolerance design "involves tightening of tolerances on parameters where their variability could have a large negative effect on the final system." (9) Tolerance design normally results in higher costs as variability is reduced through the use of special materials or components and extra processes. Even so, not all variability can be eliminated.

Typically, the system design and tolerance design steps are emphasized, resulting in a high cost product. However, employing robust design, a systematic approach to determining optimal levels of design parameters, can lead to a lower cost product. (9) Using robust design, the parameter design phase can result in performance levels that make costly tolerance design unnecessary. (7:96) Rather than eliminating variation, which is impossible, robust design minimizes the effect of variation. (5:160) Also, the design can often be completed earlier than if only the system design and tolerance design steps were completed.

Hamada explains how robust design concepts can be used to improve reliability. By explicitly addressing the interactions between control factors (that is, the design parameters that are controllable) and noise factors, combinations of control factors with robust reliability can be identified. (4:9) The resulting product will be inherently reliable with minimum variation in reliability due to noise factors, such as the weather.

Future Opportunity

One of the options contained in the *Space Launch Modernization Plan* is to "evolve current expendable launch systems." This EELV option, currently being pursued by the Air Force, involves completing existing launch contracts and evolving a new family of launch vehicles based on existing vehicles for the range of payload weights currently launched by Delta, Atlas, and Titan ELVs. (3:17)

The Moorman Study Group commented on three factors affecting space launch reliability: complexity, flight rate, and design stability. Delta, the launch vehicle with the highest reliability (100% over the last 5 years compared to 84.2% and 85.7% for Atlas and Titan, respectively), is the least complex (for example, fewer stages), has the highest flight rate (40 flights in the last 5 years compared to 19 and 14 for Atlas and Titan, respectively), and has the most stable design (fewer engineering changes required for each flight). (12:44) These three factors make intuitive sense, as they all would contribute to a shorter learning curve and a higher experience level (time to work all the "bugs" out). While one launch vehicle in the EELV family may be more complex than the others in order to provide higher performance levels (carry more weight), all vehicles in the family would be based on the same, standardized technology. When taken in aggregate, flight rates for this one standard technology would be high and the design would be stable. The use of robust design concepts, in addition, would produce even higher reliability.

Flight rates for the EELV should not be limited to only government launches. The EELV should be a launch system that can be used for both government and commercial launches. The EELV is expected to reduce recurring flight costs from $90 million to less than $80 million per flight for Atlas-class launches and from over $250 million to less than $150 million per flight for Titan-class launches. (3:13,18) In addition, as flight rates increase, fixed costs will be spread over more flights; therefore, total costs per flight will decrease. The lower cost, and resulting lower price, should make the United States space launch industry more competitive on the global market for commercial launches. As the total number of launches increases, the resulting experience level will contribute to higher reliability rates and, thereby, potentially significant reductions in total failure costs.

In addition to launch failures, the EELV program should address launch delays. Robust design choices could be made for the EELV that result in the elimination of most launch delays. Robust design results in a product that is inherently more reliable. Therefore, during pre-launch tests, fewer problems should be encountered. The time devoted to pre-launch tests serves as a final opportunity to check the launch vehicle components as well

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AFIT

The Doorway to Logistics Success

The Air Force Institute of Technology (AFIT) gained a new commander 20 January when Colonel Ronald D. Townsend become the 33rd Commandant of the Institute. Prior to his assuming command at AFIT, Colonel Townsend was Chief of the Weather Division, Directorate of Operations, Headquarters Air Combat Command, Langley AFB, Virginia. His previous tours of duty include assignments in the Pentagon and Okinawa as well as Headquarters Air Weather Service and Headquarters Military Airlift Command. He is a distinguished graduate of Squadron Officer School and Air Command and Staff College. He completed Air War College by seminar and is a graduate of the Industrial College of the Armed Forces and the National Defense University Senior Research Fellow Program.

The 1996S Graduate School of Logistics and Acquisition Management students will be arriving in May 1995. Specific areas of study for these students include logistics management, acquisition logistics management, supply management, maintenance management, transportation management, systems management, contracting management, cost analysis, software systems management, and information resource management.

If you have a thesis topic to suggest, please contact a faculty member to discuss the topic first by calling DSN 785-7777, extension 3300, or Commercial (513) 255-7777, extension 3300. Thesis research topic proposals should be submitted to Lt Col Jacob V. Simons, Jr., Assistant Dean for Research and Consulting, AFIT/LAC, 2050 P Street, Bldg 641, WPAFB OH 45433-7765 (DSN 785-7777, extension 3312). For a copy of the latest *Call for Theses* which details the topic suggestion process, please contact Lt Col Simons.

(Major Jannett Bradford, AFIT/LAL, DSN 785-7777, ext 3328)

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as the payload to further mitigate overall risk to launch successs. A more reliable launch vehicle should contribute to a shorter time line for pre-launch checkout. Using robust design concepts, reliability will be designed in rather than being inspected, tested, or engineered in during pre-launch processing, as is attempted currently. (13:20) More of the problems encountered during pre-launch processing should be correctable by maintainers, without costly engineer involvement.

Although subject to review, the *Draft Operational Requirements Document (ORD) for the EELV* contains specific reliability and schedule dependability goals for the EELV. These goals are 98% predicted spacelift vehicle design reliability, with 90% probability of launch within 7 days of the scheduled launch date. See Table 1. The *Concept of Maintenance for Spacelift Systems* echoes the 98% reliability requirement (1:11).

Reaching these goals could result in average savings of at least $150 million per year (half the current annual average cost of failure of $300 million) from fewer launch failures. Additional savings could accrue due to fewer launch delays. Robust design methods should be used to achieve these reliability and schedule dependability goals. As the *Draft Space Logistics Master Plan*, dated 31 May 1994, states, "We can no longer afford to lose a program's entire yearly budget on one failed launch." This plan's long-term goal is to raise space launch reliability to 99.9%. Having the goal is the first step toward achieving that level of reliability.

Summary

Due to the high cost of failure, achieving near-perfect reliability will be a key performance parameter for the EELV family of launch vehicles. With robust design maximum reliability can be attained at the least cost. By insisting on maximum reliability through the use of robust design concepts, the Air Force can share design accountability with the contractor to ensure success for future EELV missions.

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A Method to Get Rid of Hazardous Materials Quickly, Legally, and Cheaply

Late in 1994, the 36th Air Base Wing Logistics Group, Andersen AFB, Guam, Hazardous Materials (HAZMAT) working group faced a potentially serious problem in managing HAZMAT. Like many other organizations, we opened a pharmacy to resolve this. To improve our operation, we sought guidance which, except for PRO-ACT (an environmental information clearinghouse), was hard to get. So we looked at our Navy counterparts on island. The Navy has a Ship Repair Facility (SRF) and Fleet Industrial Supply Center (FISC) here. Both are substantial operations that use much HAZMAT. We found their programs were light years ahead of ours.

The Navy has eight other FISCs worldwide (Norfolk, VA; Charleston, SC; Jacksonville, FL; San Diego, CA; Puget Sound, WA; Pearl Harbor, HI; Oakland, CA; and Yokosuka, Japan). Sigonella, Italy will eventually have one also. Each FISC has a Hazardous Material Reutilization Center (HAZMINCEN). That's Navy for pharmacy. What we found interesting is that the HAZMINCEN will serve, or partner with, non Navy units.

We subsequently signed an Interservice Support Agreement (ISSA) with FISC Guam, adding a new dimension to our pharmacy procedures. This agreement is the first of its kind in the Department of Defense. Our Supply squadron is transferring HAZMAT to the FISC Guam HAZMINCEN. The FISC will store, stock, and deliver our HAZMAT (we keep five days worth in our pharmacy). The change is nearly invisible to base customers.

Our ISSA so far has cut three major ECAMP (Environmental Compliance and Management Program) write-ups without cost. The outcome is that we will have less HAZMAT on Andersen and Guam, and we will free up about 6,200 square feet of indoor storage area. This agreement lets us operate with no constraints. It's *win-win* for all concerned.

Shortly after learning of this program, we got rid of several hundred gallons of paint we thought we would have to waste. After we told PACAF/LGQ about it, Hickam AFB got rid of 47 pallets through the Pearl Harbor FISC, all at no charge. Hickam saved $200,000 that it would otherwise have had to spend on waste disposal.

By using the Navy HAZMINCEN, our cost avoidance for 1994 was $799,432.11. This included material ($128,662.38) and disposal avoidance ($670,769.73). Disposal avoidance does not even include shipping costs off the island. Our total cost avoidance as of 1 May 1995 was over $850,000.

Now for a few of the specifics about our agreement. The Navy HAZMINCEN:

(1) Reports our HAZMAT storage (Resource Conservation Reporting Act (RCRA) and Emergency Planning Community Right to Know Act (EPCRA) 301/302). We report only our usage.

(2) Issues HAZMAT in only the quantities needed. Its larger organization allows economies of scale to take the pharmacy concept one step better.

(3) Advertises our excess HAZMAT worldwide, real-time, and consolidates all our excess, centralizes issues, and provides free redistribution of excess HAZMAT.

(4) Takes the unused portion back, if uncontaminated.

(5) Offers a closed loop on HAZMAT life cycle management issue and return. We take our quart, use it, ensure we did not contaminate the container, then return it to FISC. FISC tracks the container.

(6) Provides training on shelf life extension.

(7) Transports HAZMAT to and from the HAZMINCEN.

(8) Examines our facility, analyzes our waste stream, and recommends methods of improvement. This could potentially be a big money saver.

(9) Provides a list of environmentally safe substitutes.

What does it cost? Very little. We pay the cost of the material—period. There is no value added charge. This means we pay the same as through Supply. We still have our own pharmacy, but we are eliminating redundancy and have less to report and to store.

These programs are standard Navy wide. Since there are usually several DOD installations convenient to a FISC, it may be worthwhile to call code 82H at the nearest FISC and check it out.

For further information, call:

36 ABW/LGX, SSgt Hughes, DSN 315-366-3290
36 ABW/LGSDH (HAZMAT pharmacy), DSN 315-366-4770
36 ABW/MG BioEnvironmental, DSN 315-366-6219
FISC Guam code 82H, Mr Tom Nelms, (commercial) 671-339-4628
CONUS information — NAVSUPSYSCOM 452, LCDR Ed Payne, (commercial) 703-607-1206

Lieutenant Colonel Nicholas S. Costa
Deputy Commander
36th ABW Logistics Group
Andersen AFB, Guam

Environmentally Preferred Products Catalog Available

The Defense General Supply Center (DGSC), Richmond, Virginia, has published their first catalog of Environmentally Preferred Products. The DGSC is one of the Defense Logistics Agency's five supply centers. It manages federal stock group 68 which encompasses hazardous as well as environmentally preferred chemicals.

The new catalog contains over 300 stock-numbered items available right now from DGSC through the normal requisitioning procedure. Some of the product categories are Aqueous Cleaners/Degreasers, Deicers, Aircraft Cleaning Compounds, Spill Control Products, Marine Cleaning Compounds, and Recycling Equipment.

The catalog is being distributed to DGSC's military and federal civilian customers worldwide. It includes useful voice and fax telephone numbers for DGSC technical staff assistance. Copies may be obtained from DGSC's Marketing Office. Call DSN 695-5699, or (800) 352-2852; Fax DSN 695-5695, or (800) 352-3291.

Stephen J.Perez
Program Executive
Marketing Office
Defense General Supply Center
Richmond, Virginia

Air Force Journal of Logistics Fifteenth Anniversary: A Brief History

With this issue, the *Air Force Journal of Logistics* is 15 years old. What follows is a brief description of the Journal as originally envisioned, a summary of key events/activities leading to its evolving from a four-page newsletter to its present form, and a listing of its editors since its inception in 1980.

General

The first *Air Force Journal of Logistics (AFJL)* was the Winter 1980 issue. This was on target with the publication schedule set on 29 May 1979 when USAF/LE (Lt Gen Billy M. Minter) approved the concept of a professional logistics journal for the Air Force and directed its establishment.

The purpose, form, content, operating structure, and basic editorial policies reflected in the *AFJL* in the initial and subsequent quarterly issues were the culmination of a series of events, discussions, briefings, and correspondence occurring over the previous six years (See Chronology of Key Events).

Purpose

The fundamental purpose of the *AFJL* was to provide an open forum for presentation of research, ideas, issues, and information of concern to professional Air Force logisticians and other interested personnel. In the tradition of serious professional journals, the *AFJL* was to be a way (for those willing to have their work and ideas examined and judged by the other members of their profession) to publish the most significant unclassified research, improvement efforts, and conceptual thinking occurring in and about Air Force logistics. Basic objectives were to:

- Stimulate additional thought on professional topics.
- Encourage creation of alternate, more effective approaches to logistics operations and problems.
- Educate readers in and outside the Air Force on the complex and essential nature of logistics in assuring overall military effectiveness of the Armed Forces.
- Inform the entire logistics community of significant developments in various parts of the logistics system.
- Instill a deeper sense of mission and profession in Air Force logistics personnel at every level.

Essential to such an undertaking was the principle that the *AFJL* would, in fact, be an open forum where established Air Force logistics authorities would encourage and tolerate rational dissent from and constructive criticism of recent or current policies, procedures, and operations in the interest of improving Air Force logistics in the future. These basic operating conditions, critical to a viable professional journal were accepted, supported, and met many times over throughout the *AFJL's* fifteen-year history.

Target Audience

The initial primary target audience of the *AFJL* was the 30,000-40,000 officers, top three enlisted personnel, and professional-level civilians who constituted the core of career Air Force logistics managers and leaders in maintenance, supply, transportation, contracting and acquisition, munitions, engineering and services, and logistics plans and programs. In addition, it was recognized that the better the *AFJL* met its basic objectives as a professional logistics journal and maintained a high level of quality and breadth of scope in its contents, the more likely a secondary readership would develop. Such secondary readership, it was thought, may include other members of the logistics community aspiring to join the primary group such as other military personnel, industry, and the civilian research and academic community. Today, the primary target audience has grown three-fold, and the secondary audience now includes other US military Services, other Department of Defense agencies, industry, and academia.

Specifications

The printing specifications which were approved for the *Air Force Journal of Logistics* on 3 August 1979 by USAF/DA and which guided production of the *AFJL* during 1980 were as follows:

Size - 8" x 10 1/2" (now 8 3/8" x 10 3/4")
Pages - 28 pages (plus cover) (now 44 pages including cover)
Stock - 120-160 litho coated book (now 60 white offset book)
Ink - Black plus one

Chronology of Key Events

Fall 1974	AFIT School of Systems and Logistics letter to USAF/LG proposing an Air Force logistics magazine. USAF/LGXJ (Logistics Analysis and Congressional Affairs Division) made OPR for project.
5 Dec 1974	Individual assigned to USAF/LGXJ, in addition to other duties, given action on the logistics magazine proposal.
6-8 Dec 1974	Basic concept, contents, and format of Air Force logistics publication developed.
9 Dec 1974	Deputy Chief, USAF/LGXJ, briefed on journal concept.
Feb 1975	"Dummy" magazine produced by Pentagon Graphics.
May 1975	USAF/LGX briefed on journal concept and responded positively.
Jun 1975	Approval of USAF/LG to sound out rest of USAF/LG staff on the concept.
Jul 1975	USAF/LG directorate and USAF/LGX division favorably responded to concept.
Oct 1976	Air Force Logistics Management Center (AFLMC) established.
Jan 1977	AFLMC published first AFRP 400-1, *The Pipeline* (4-page quarterly newsletter).
23-24 Apr 1979	Discussions between AFLMC/CC and USAF/DAP on specifications and requirements for establishing a professional logistics journal.
29 May 1979	Proposal to establish the *Air Force Journal of Logistics* briefed to and approved by USAF/LE.
Jun-Jul 1979	Discussions between *AFJL* editor and USAF/LE, USAF/LEX, USAF/LEXY, SAF/AL, SAF/OK, and USAF/DAP civilian personnel regarding manning and other support requirements.
24 Jul 1979	Briefing to AU/CC on *AFJL* support requirements.
24 Oct 1979	*AFJL* concept briefing at USAF MPIP/LG conference.
Jan 1980	First issue of *Air Force Journal of Logisitcs* published.

Format - Primarily double column; some triple and single for variety and space

Frequency - Quarterly

Content

The following proportions and types of content guided the composition of the *AFJL* during 1980:

Cover - to include members of the Editorial Advisory Board, staff, information for contributions, and pertinent quotaton

Table of Contents - 1 page

Major Research and Articles - 19-25 pages

Regular Departments - 4-6 pages

Although a number of other departments have been added through the years, the three initial regular departments were:

- USAF Logistics Policy Insight.
- Career and Personnel Information.
- Current Research.

Long-range plans were made for the addition of several other regular features contingent on the eventual approval of an increase in number of pages.

Editorial Advisory Board (EAB)

To insure participation and representation of the entire Air Force logistics community in the *AFJL*, to bring the wisdom and insight of senior members of the profession to bear on the Journal, and to guarantee contributors that their work would be read and evaluated by senior logistics leaders (admittedly, an incentive for some, a disincentive for others), an Editorial Advisory Board was established for the *AFJL*.

The composition of the EAB was originally conceived to include most of the senior logisticians in the Air Force. As the *AFJL* took final shape in late 1979, USAF/LE and the editor agreed that a smaller EAB could accomplish the same objectives with less administrative workload. As a result, the EAB during 1980 was composed of the following senior logistician positions:

Permanent Members

Deputy Assistant Secretary of the Air Force (Logistics)
Commander, Air Force Acquisition Logistics Division
Vice Commander, Air Force Logistics Command
Assistant DCS, Logistics and Engineering, USAF
Director, Logistics Plans and Programs, USAF
Director, Maintenance and Supply, USAF
Director, Transportation, USAF
Director, Contracting and Acquisition Policy, USAF
Director, Engineering and Services, USAF
DCS, Plans and Programs, AFLC
DCS, Logistics Operations, AFLC
DCS, Maintenance, AFLC
Dean, School of Systems and Logistics, AFIT
Commander, Air Force Logistics Management Center

Annually Rotating Members

In addition to the permanent members, two major command deputy chiefs of staff for logistics and an air logistics center commander were invited to represent their organizations on the EAB for one year, at the end of which the representation would rotate to two other MAJCOMs and another ALC. During 1980, these rotating membership positions were as follows:

DCS Logistics, USAFE
DCS, Logistics, ATC
Commander, Oklahoma City Air Logistics Center

(Note: The Commander of Warner Robins Air Logistics Center was initially invited to serve on the ALC/CC position but, because of anticipated retirement in early 1980, declined. The senior officer, OC-ALC/CC, among the remaining ALC commanders, was invited to serve and accepted.)

In late 1980, in anticipation of the need to fill the rotating memberships in 1981, USAF/LE invited the TAC/LG, the SAC/LG, and the Warner Robins ALC/CC to serve in 1981. They accepted.

At Large Members

USAF/LE maintained the option to invite up to three non-active duty personnel to serve two-year terms on the EAB. Civilians as well as retired and reserve military personnel were eligible.

Contributing Editors

To insure publication of accurate and relevant information in the recurring *AFJL* departments and to provide a means of direct input and participation in the *AFJL* from the key centers of Air Force logistics research, study, and conceptual thinking, incumbents in selected positions in these centers were invited to serve as contributing editors. Organizations represented included Headquarters USAF, Air Force Institute of Technology, Air Force Logistics Command, the Air War College, Air Command and Staff College, the Air Force Academy, PALACE Log, and the Office of Civilian Personnel Operations.

Editorial Staff

During 1980, the Editor was the only permanent staff assigned to the *AFJL*.

Ordinarily, publication of a professional journal meeting the high quality standards, variety of contents, size, and frequency set for the *AFJL* would require a staff of more than one. This staffing was included in the *AFJL* concept from the beginning, and a civilian associate (assistant) editor position requirement was identified. Because of manning authorization changes within the AFLMC and other parts of the logistics community in 1980, this position was not formally established or filled. An assistant editor position was subsequently added in 1982. Required graphics support was provided through requests to the Air University contract graphics section.

The *AFJL* was published under these extraordinary circumstances in 1980 through the full utilization and positive support of the secretarial, administrative, printing, and graphics resources already existing and available in the AFLMC and Air University.

Air Force Journal of Logistics Editors

Winter 1980 - Summer 1981	Maj Pember W. Rocap
Fall 1981 - Spring 1982	Maj Theodore M. Kluz
Summer 1982 - Spring 1985	Maj Theodore M. Kluz Jane S. Allen (Assistant Editor)
Summer 1985 - Summer 1987	Lt Col David C. Rutenberg Jane S. Allen (Assistant Editor)
Fall 1987 - Spring 1991	Lt Col David M. Rigsbee Jane S. Allen (Assistant Editor)
Summer 1991 - Winter 1992	Lt Col Keith R. Ashby Jane S. Allen (Assistant Editor)
Spring 1992 - Spring 1992	Jane S. Allen (Acting Editor)
Summer 1992 - Winter 1994	Lt Col Bruce A. Newel Jane S. Allen (Assistant Editor)
Spring 1994 - Present	Lt Col Bruce A. Newell

Control of Space Debris—The Challenge of the Future

Kathleen Van Orsdel

Introduction

For years, we have been concerned about the earth's environment. However, more recently, concern has been growing about the space environment and the problems affecting future space flights. Space debris, whether left purposely or inadvertently in space, is beginning to create major problems for space travelers. The possibilities of collisions with either manned or unmanned space vehicles have dramatically increased. While cleaning the terrestrial environment is important, the logistics of protecting and cleaning our space environment is also important. The potential for accidents will grow dramatically as space travel increases. Orbits are congested and space is not as "infinite" as we once thought.

The Past

As more and more rockets were launched into space, man profited and learned more on earth. Among the many satellites launched were TIROS (Television and Infrared Observation Satellites) weather satellites. These were strategically placed to monitor weather patterns and track specific changes, thus teaching modern weathermen more about upper atmospheric disturbances than was ever known before. Communication relay stations were launched and stabilized to create continuous "lines" for placement of communication sites throughout the world with the INTELSAT (International Telecommunications Satellites). As a result, long distance communications were established for some out-of-the-way places and enhanced for others. Both civilian and military satellites were launched to collect data, and an even greater number was launched to explore space. They were programmed to perform their given mission for a specified time and then, when the mission was done, they were abandoned. These useless pieces of metal were then left to orbit the earth. "More than 6.5 million pounds of man-made junk encircle our planet, cluttering what once seemed empty and infinite, and every bit of the flotsam is a menace—moving at orbital speeds as high as Mach 20." (1)

Space launches and the race for space captured the imagination of the world. Scientists, driven to answer age old questions of creation, had little regard for the impact of their actions on future generations. Furthermore, based on our knowledge of space, no one gave much thought to the problem of "space junk."

Space debris has many characteristics: It is small pieces of metal broken from a spacecraft; it is a larger chunk of that craft after it breaks up; and it is a chip of paint created during a collision. Space debris has been created in some degree every time a rocket was fired into space; in some cases, leaving hundreds, even thousands of highly destructive fragments in orbit. (2) Little concern was given to the build up of orbital debris in the near-earth space environment. (3) In the spring of 1961, the first orbiting satellite blew up, creating hundreds of pieces of space debris. Much of the debris from that first satellite is still in orbit and tracked today. (4) The Soviet space station *Salyut 2* broke up in orbit, and more recently, the Soviet craft *Kosmos 1823* exploded. While creating their own debris through these explosions, little is known why these craft broke up. Some scientists believe collisions with orbiting space debris could have destroyed the craft. (5) Additionally, numerous impact marks were found in the metal of a Soviet spacecraft when retrieved by the *Salyut 6* crew. (6)

Leading scientists and interested lay persons created and attended conventions and symposiums to address the problems being created by the growing menace of space debris. The 1972 Convention on International Liability for Damage Caused by Space Objects and the 1976 International Convention on Registration of Objects Launched into Outer Space both addressed provisions and positions that were relevant to space activities and debris. The specifics addressed by each of these conventions is apparent by the name of the group and both conventions developed specific provisions for control of space debris. Enforcement was largely ignored by spacefaring nations. None of the countries involved in the space arena today take the time to register their launch data. "Both the Soviets and the US have conducted antisatellite weapons tests which generated debris, but neither country conducted prior consultations." (7) There is no evidence of any country involved in the space industry taking the time to inform other interested parties about the changes in orbit of their "already-in-place" craft.

Even the Department of Defense's Strategic Defense System (SDS) created an Orbital Debris Control and Space Asset Disposal Policy that listed among their major objectives:

- To ensure SDS elements can operate in the anticipated debris environment.
- To minimize the contribution of SDS deployment and operation to orbital debris.

While these objectives are worthwhile, they pertain only to the department creating them. The specific orbital debris research concentrated on five areas:

(1) Understanding and modeling the debris environment.

(2) Enhancing monitoring capabilities.

(3) Shielding spacecraft.

(4) Changing satellite operating procedures to minimize creation of debris.

(5) Redesigning of space systems to minimize creation of debris. (8)

However, space scientists continued to disagree on prioritization of the items of research. While some scientists believed that shielding was the only way to go, and they all agreed that space-involved nations needed to minimize creation of debris, not many could agree on the methods needed to control and reduce that which was already in space.

The Present

With considerable time and effort, North American Aerospace Defense Command (NORAD)/United States Space Command (USSPACECOM) created and maintains a catalog of space debris. This catalog, which contains more than 7,000 orbiting objects, lists debris by size and known orbit. In addition to

including active payloads, the catalog also contains listings of spent rockets, dead satellites, bolts blown off separating stages, and a listing of identifiable fragments that are 10 cm or larger. As debris is identified, it is added to the catalog in a never-ending effort to keep it current.

There are programs currently used at various sites that attempt to track and identify debris that is not already cataloged. One such program, Zenith Stare, uses a high frequency lens and stationary camera to accomplish its goal. The camera studies a specific range of open space, reacting to any movement in that range. The camera does not attempt to follow the object, rather the moving objects simply enter the screen, travel through, and exit. Technicians then attempt to identify the object at a later time through study of the developed film. Another program, Stare and Chase, involves the same type of equipment except the camera is mobile and tracks the debris throughout a given range. This is done in an attempt to identify and provide specific orbital characteristics. (9)

Engineers and scientists are using a variation of celestial mechanics that tracked stars and planets in their efforts to track debris. This process of "orbital mechanics" determines the expected location of man-made objects in space through orbit and trajectory computation. While this is a relatively new technique, it has already been used to avoid known orbiting debris through pre-planned evasive moves.

Debris orbit information is critical to maneuver the craft out of harm's way. Collision with an object as small as 10 cm can destroy a spacecraft. Debris can attain velocities of up to five miles per second (48,000 miles per hour) in orbit. A fragment the size of a marble, traveling at this speed, has the impact of a hand grenade. (5) The problems associated with cataloging orbits multiply if there is a collision—new orbits are created. Additional debris particles will be generated and old ones will have changed size (the smaller the particle, the harder it is to track with current equipment). Even if a launched spacecraft is to be placed in a deeper orbit, it must still pass through the various near-earth levels of space (troposphere, mesosphere, thermosphere); levels where a great density of debris has collected. Evasive maneuvers have become part of all launch procedural criteria. The National Aeronautics and Space Administration (NASA) has included $3 million in their budget to study collision hazards and has ordered their contractors to intensify efforts and to be more specific about strategies needed to contend with debris. (10)

While evasive maneuvers protect the space shuttles, there comes a time when there is no viable alternative. The collision threat is very near to the heart of scientists and technicians developing the Space Station *Freedom*. Because of its size, the Space Station *Freedom* would not have the maneuverability to avoid debris. A human crew member could be killed working outside the spacecraft if struck by debris (remember that piece of debris hurtling through space at five miles per second). Consider also the not so obvious—hazardous materials left in orbit or nuclear reactors that could threaten other highly valuable spacecraft, equipment, or other materials with national security value.

Something must be done about the debris in space. We can no longer pretend the problem does not exist. "Space [debris] proliferation as a genuine threat has come of age." (11) As more and more countries become involved in space, the problem intensifies. Current measures used by many spacefaring nations to combat debris creation include lower orbits for payload fairings and spent rockets to insure they fall back to earth; depletion burns to insure no fuel remains to cause explosions in space; and "park" orbits. (12) US space policy mandates that US spacecraft developers and operators must minimize orbital debris created through operating their launch systems and spacecraft. (8) The one major drawback to this mandate is very obvious; the United States cannot control other nations.

Space program engineers have progressed through debris evasion maneuvers to debris creation prevention, but these measures do not address the problem facing us today—what do we do with the junk that's already in space?

The Future

Working with ideas for the future involves a mental exercise of simply letting go. Visualizing something as strange as what you might see in a Star Trek episode is not as far fetched as you might think. With just a little work, some rather strange ideas can become reality.

The worldwide community is developing solutions concerning space debris that cover some of the ideas already discussed. While hardening or shielding spacecraft is one method considered, the shield itself may not always be able to withstand the velocity of a strike. Maneuvering to avoid debris involves more fuel to provide the necessary thrust. Another solution considered is a reentry program for spent satellites. This would involve boosting the spacecraft into a decay orbit. This process is gradual and slow and does not allow for control of the spacecraft on its return to earth. The object stays in an orbit as debris, and as it begins an uncontrolled reentry, it may or may not completely burn. Parking spent satellites in a deep space orbit is also being discussed. This requires an extra amount of fuel in order to boost the satellite into the orbit. In addition, this method only moves the object into another orbit where it remains—as debris. The common thread which connects these methods is fuel—fuel in larger amounts; fuel in greater capacity. Additional fuel increases craft weight, complicating launch. Current launch capacity cannot handle some of the associated problems with extra craft weight. There must be another way! Collection techniques are the latest method being considered. Some of the technology is in place; some must be developed.

The shuttle *Endeavor*, on its first flight in May of 1992, carried a replacement booster for an INTELSAT satellite that was already in orbit. The crew captured the INTELSAT, mated it to the upper stage replacement, and redeployed the satellite from the shuttle. (13) Smaller, free-flying spacecraft with the ability to perform on-orbit maneuvers can and are being developed. (8) The existing robotics capability to capture another orbiting object can be further developed to include retrieval of smaller articles of debris. Manned vehicles with such robotics can use their maneuvering ability to position the spacecraft in such a manner that the greatest number of objects can be retrieved safely. Arizona engineers are currently developing a robotic junk processor that uses infrared radar and laser beams to scan for debris. Throughout its lifespan, it would collect debris. Once it has either been filled to capacity or is no longer able to function, ground controllers would have the option of destroying the craft through a slow reentry burn or return it to earth in a controlled ocean splash down. (14;7) The options would be exercised based on the obvious costs involved and the potential gain from the collected debris.

The maneuverability of *small* manned or unmanned spacecraft may also be key in the development of space junk collectors. A smaller unit has more maneuverability and could change orbits at will, based on the operator's whim. A small unit would not be able to process a large amount of oversized debris; however, if the unit were part of a larger collection of units, it

could "store" the collected debris after each pass. The smaller units would use robotics capability to gather debris and return to a larger space unit (home station) and transfer the debris to the holding area. The home station could be as close as a few hours or as far as a few days journey. The robotics armatures could be controlled manually or by computer. These armatures could have a "flex" capability or the end of the armatures could be magnetized. The crafts' robotics equipment would determine the size of the debris to be collected. The holding bay at the home station could be internal to the spacecraft or external in a net-type suspension. A net suspension would possibly hold more, but might create more problems on its return to earth. Time in space would vary, depending on mission requirements. Time away from the home station would vary, depending on the fuel capacity of the smaller maneuverable units. Mission requirements would be based on the amount of debris in the particular orbit used.

Ground controllers would keep in contact with the humans in space (if the home stations are manned units) to keep abreast of the types of debris being collected. Of course, the idea is to clean the debris from space, but, profits gained from the project are a side benefit—and need to be considered.

Does this sound like science fiction? Hardly! The technology is in place today! At this time, the ideas are cost prohibitive for any single nation to pursue, however, joint space ventures are already planned. This "junk collector" could be owned by all nations involved, each sharing in the costs of operation and each sharing in any return gains. Just as junk is recycled on earth, collected debris could be recycled, and space junk recycling programs could be developed. Making space junk recycling profitable would encourage the unified nations involved to support the program.

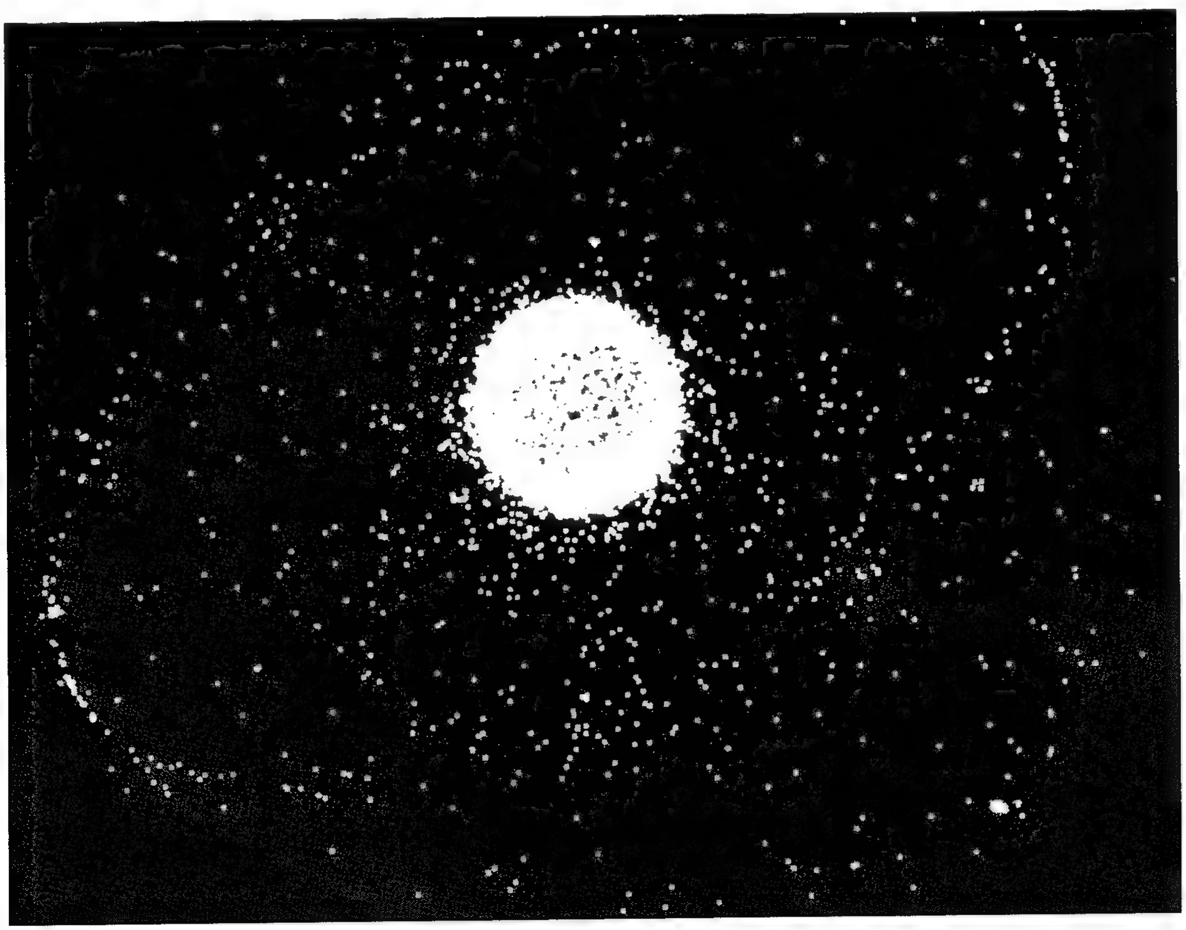
Today, there are spent satellites parked in deep space orbits. These satellites are dead only because they ran out of fuel. The computer systems are still good, much of the electronic equipment is still functional. Entrepreneurs would find many uses for the myriad of space debris returned. The possibilities that exist for reuse could be limitless. Using the concept of a United Nations Space Debris Collection Unit, all nations would have input into the "reuse" potential. All nations would benefit jointly from such a program.

Conclusion

Whether or not you agree with the idea of a space junk collector, I think everyone would agree that a problem exists and must be addressed. The figure below is a computer generated image illustrating earth's very thin ring formed from man-made orbital debris.

The space programs of the future will give more attention to the debris problem. DOD Space Policy states:

> DOD will seek to minimize the impact of space debris on DOD space operations. Design and operation of DOD space tests, experiments, and systems will strive to minimize or reduce the accumulation of space debris consistent with mission requirements and cost effectiveness. DOD will work with appropriate agencies and organizations outside DOD to develop measures to mitigate problems caused by space debris. (15)



(NASA Photo, Courtesy of United States Space Foundation)

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(Continued from page 31)

helping. He patented plans to make an orbiting sweepercraft to reduce orbital trash. (6) Petro's sweeper would have 1/4 mile-long blades that are several hundred feet wide. A radar monitor would spot debris and the panels would rotate to intercept. The particles would either be embedded in the blade, or tear through. In the latter case, enough energy would be dissipated to reduce damage of future impacts. The only problem remaining to solve is the ability to select proper targets to intercept. The challenge is to *not* take out an active satellite!

Summary and Conclusion

I have examined some of the ways to apply ILS principles to the problems plaguing the space industry. In addition, I presented maintainability factors that must be designed into the systems, and emphasized standardization throughout all of the programs. Scientific studies from space are increasingly critical; however, the logistical aspects of space programs are enormous. To meet the demands, it is imperative to develop quality international cooperation; several ideas were presented. As one example, the International Space Station is a proving-ground for the necessity of supportable development and global teamwork. Next, I reviewed the benefits and concerns of working with other nations.

Also, global environmental problems are of increasing consideration. I demonstrated the benefit of changing our view of the earth into one we would use in developing any sustainable system. This can only be accomplished by "stepping back" and judiciously utilizing space-based monitoring systems. Again, the enormity of such programs beckons for international cooperation and many examples and uses of these projects were listed. Finally, as the upper atmoshphere grows in use, I discussed the issue of debris that begins to play at the disposal end of the life-cycle.

In conclusion, logistics directly impacts the success of our space program, which in turn impacts every citizen of our planet. We must remember the words of Socrates who, even in the 5th century BC, realized "Man must rise above the Earth—to the top of the atmosphere and beyond—for only thus will he fully understand the world in which he lives." (17:57)

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International Cooperation and Concerns in Space Logistics

Darrin Guilbeau

Introduction

Logistics management is a broad field with many diverse applications. In this field, we are often trained to look at systems and study cost aspects in a total life-cycle phase. Our goal is to manage a program in order to have the most efficient process possible and at the best cradle-to-grave cost. It is commonly said that we control all of the rights: the right product in the right quantity, time, place, and at the right price. Quite possibly, there could be no more critical area for this to happen in than the space program. This paper will address logistical aspects of international cooperation (particularly between the US and Russia) in meeting current and anticipated goals of the space community. Available capital and capabilities are at levels that dictate the necessity of applying strong Integrated Logistics Support (ILS) principles. Even so, we will need help from other sources. As science fiction writer Isaac Asimov proclaimed "If I could summarize the legacy of the space age in a single word, it would be *globalism*." (17:53)

Space Logistics Costs

Traditionally, logistics support considerations for space systems have been left out of up-front design provisions. They have the back seat to operational requirements. Overall, the costs to field and operate space systems have become enormous. The space shuttle, for example, took $14 billion (1985 basis) to develop and, depending on accounting systems, eats up $42 million to $150 million per flight. (4) Original projections were not even close to this level. More recent estimates from the National Aeronautics and Space Administration (NASA) claim the average cost of hardware, software, and contractor manpower (derived by time-phasing the actual operations costs, using an eight-flight-per-year manifest) runs $363 million per flight.

Providing capabilities in space demands strict fiscal responsibility. Recent budget reductions are wreaking havoc on planners. Unfortunately, several areas of logistics are often the first places hit. Logisticians must fight to maintain their place in the development stages of programs. Current costs from earth-to-orbit are running between $2,000 and $4,000 per pound. Consequently, new technologies must bring that figure down by orders of magnitude if we are to supply the near-space environment with desired systems. Opportunities for savings abound!

On-Orbit Maintenance Design Considerations

The unique environment of space presents many challenges to logisticians and space system designers. One of International Space Station *Alpha's* (formerly Space Station *Freedom*) taskings will to act as a space-repair depot, in other words, to accomplish on-orbit maintenance on other space vehicles. This section identifies the on-orbit maintenance considerations that should be made when designing a space vehicle or space system.

Simplicity

Of all of the lessons learned in space, an overriding consideration to adhere to is Keep It Simple. This principle should be applied to all of the areas concerning on-orbit maintenance, particularly in maintainability, access, and standardization. Other areas where this principle is particularly important include modularity, simulation, logistics, and configuration control. (9:23)

Maintainability

The philosophy of maintainability should be incorporated from the very start of program design if it is to be successful. The astronauts must have a say in this area as early as possible as well as quality assurance and safety specialists. Designers must plan ahead for problems and give conservative timelines for tasking. They should remember that most tasks that are hard to perform on the ground are much tougher in space. Human engineering criteria should be simple and explicit to reduce possible mishaps. Designers must ensure that as many subsystem orbital replacement units (ORUs) be incorporated into the vehicle as possible. Another necessity is the availability of technical documentation. Changes in design must be closely monitored through an agressive and accurate configuration management program so that spares, tools, and replacement units are compatible with flight hardware. Most importantly, lessons learned from previous experience in space must be heeded. Unfortunately, valuable information is often forgotten.

Access

Access is a key topic also. ORUs must be placed within easy reach and eyesight. Considering the attire of the crew, all connectors and doors must be easily operated. The less frequently tools are needed, the easier maintainability will be. Double-high bolt heads and self-retaining fasteners should be used. The movement of loose parts, equipment, and tools should be minimized. Access should not be cluttered with crowded ORUs or tight cable routing. Proper restraints are a necessity. Among the most common are foot restraints, hand holds, and tether points. Translation aids such as hand rails, slide wires, and safety tethers should also be used. Instead of designing permanent foot restraints into the vehicle, designers should allow for locations where astronauts could merely clip into place foot restraints, thereby reducing weight and allowing for flexibility.

Standardization

Standardization is probably the most important aspect of all. Not only would on-orbit maintenance benefit, but the entire space program would as well. We must examine mechanical, electrical, fluid, optical, thermal, and communication interfaces. Prior challenges with inter-service standardization of equipment are a great place to begin finding solutions to international compatibility. Training would be minimized with fewer tasks to learn. Also, the varieties of fittings, connectors, fasteners, and tools required would be significantly reduced. Fit checks would not be as great a problem as well. ORU interfaces should be standardized in the event that upgrades are necessary or adaptations are needed. Standardization also reduces the cost and size of warehousing and tool kits.

As demonstrated, there are many areas to apply logistics principles. Maintainability, accessibility, and standardization are the key components in developing an on-orbit maintenance capability. In all steps of development, the Keep It Simple principle plays an important role and must be remembered. In the past, a large number of spacecraft have been placed out of operation due to equipment failures after launch with no provisions available for retrieving the vehicle or to repair it on-orbit. If the above items had been considered initially and implemented into these past programs, perhaps most of those vehicles would still be in operation today at reduced costs to the space program.

Space Station *Freedom*

For unknown reasons, such hard-learned lessons are often forgotten. Plans for Space Station *Freedom* were first announced in 1984 by Ronald Reagan. By 1992, it was supposed to be in operation. Political fights over design, use, and funding have caused seven redesigns and almost killed the program in 1991. Buzz Aldrin, the second man on the moon, has watched all this with growing consternation. He is working to save as much as possible of what has already been developed. The US and its partners (Canada, Japan, and the European Space Agency (ESA)) must come up with a faster, cheaper, and more politically-attractive package.

Fortunately, we have some relatively new options in assistance. The Russian's Energia is capable of lofting 220,000 pounds into Low Earth Orbit (LEO). Our largest booster, Titan IV, and the shuttle are limited to one-fourth of that payload. Energia and the shuttle could take payloads up in tandem, with Energia doing the heavy lifting. Then, the shuttle would rendezvous with those payloads, bringing astronauts up for assembly.

Aldrin has drafted several scenarios to get the program up and running.

> Right now, we're going to need about thirty shuttle launches to get the baseline station into orbit, because you have to break up station components to fit inside the shuttle bay. But with the Energia, we could launch those pieces in bigger chunks and get them up a lot faster—and at the prices the Russians are quoting these days, a lot cheaper, too—while the shuttle could do what it does best: bring humans up to put it all together and deal with the unexpected. (8)

Aldrin feels the main elements could be lifted with only four Energia launches, each followed by a shuttle mission.

> We could take the stationtruss (the crosspiece on which the station's pressurized modules, solar panels, radiators, and external experiments are hung) up first. Next would be the US lab and habitation modules. After that, we'd take the JEM (Japanese Experimental Module) and the (European Space Agency's) *Columbus* module. (8)

He also envisions a new large-volume, single launch model of *Skylab* added to *Freedom.*

> The original planned inclination for *Freedom* was 28.5 degrees, in contrast to the optimal Energia inclination of 51.6 degrees—where the *Mir* orbits. In theory, we could do all that by ourselves in a low-inclination orbit, but whatever you decide to do, you need everything to be in the same orbit. And the trouble is that the booster capable of putting all that up faster, cheaper—and maybe safer—doesn't belong to us. Furthermore, it would take at least five years and billions of dollars to develop it. (8)

Aldrin's views have a big impact on policymakers. Fortunately, many have listened. "If we went for the higher-inclination orbit and used Russian assets together with our own, we could all benefit." He states, "We could either construct a facility to co-orbit with the *Mir* or join forces with the Russians to upgrade the *Mir's* capabilities and attach *Freedom's* habitation module to it and triple its capacity." (8) Congress wanted the 28.5 degree inclination, but the reality is closing of having everything in orbit with the *Mir*. Politically, we do not appear able to launch American craft from Russian soil, or vice versa, at any time in the near future, so all vehicles will have to be launched from native territory.

The latest redesign, successfully integrating a majority of these suggestions, has completely revamped the program and informally changed the name from Space Station *Freedom* to International Space Station *Alpha.* The systems design review was completed in late-March 1994. Construction in space is scheduled to start December 1997 with a completion date of mid-2002. It will require 34 space flights (16 US, 13 Russian, 2 ESA, 1 Japan, and 2 joint US-Japan missions) in three phases to build. Phase 1 has already started. The goal is to obtain cooperative in-orbit experience with astronaut/cosmonaut flights in US space shuttle and *Soyuz/Mir 1* flights. Phase 2 will build the "core" of the station in 1997-1998 with Phase 3 completing the station by 2002.

The current configuration calls for the space shuttle to dock with the *Kristall* module of the Russian *Mir* Space Station using the Russian-developed Adrogynous Peripheral Docking System (APDS) mounted on top of a US-developed external airlock. As part of the Internatonal Space Station, this configuration will become the largest space platform ever assembled as well as the largest international scientific endeavor undertaken in history. In a cooperative effort, 13 nations will draw upon the resources and scientific expertise of each other, including the United States, Canada, Italy, Belgium, Netherlands, Denmark, Norway, France, Spain, Germany, the United Kingdom, Japan, and Russia. The *Progress* (unmanned resupply ships) vehicles will automatically rendezvous with no required crew involvement to transport food, propellant, and supplies to the *Mir*. The US space shuttle is anticipated to dock with *Mir* between 7 and 10 times from 1995-1997. The first mission is STS-71 (June 1995) which will also bring Thagard home from his tour on the *Mir*, will be followed by STS-74 in October 1995. In three-month blocks, American astronauts are scheduled to spend nearly two years on *Mir.*

The program has been made more capable and the investment-to-date saved by applying ILS principles and incorporating 75% of the hardware in development for *Freedom.* Modules have increased from 6 to 10; the pressurized volume boosted from 23,000 cubic feet to 42,443; crew size has grown from 4 to 6; and the EVA maintenance activity/year decreased from 216 to 197. The management structure has been cut to a single core NASA team and prime contractor. Direct accountability and single lines of authority are organized through integrated product teams. These teams are proving the superiority of concurrent engineering philosophies and end-to-end system integration techniques. On-time product delivery is now the norm with a streamlined management approach and reduced bureaucratic layering.

The space station is an excellent example of how cooperation is necessary for many programs to even get off the ground. Governments are finally beginning to cooperate with each other on a scale large enough to really empower space exploration and development programs.

Current International Efforts

With a staff of 3,000, Matra Marconi Space (MMS) was the first fully integrated European space company. They are developing equipment for satellite and systems such as guidance,

navigation, on-board computer controls, telemetry, instrumentation, robotics, and image processing components. The Italian Space Agency (ASI - Agenzia Spaziale Italiana) has had substantial budget increases. (16) They are now the third largest member of the European Space Agency, behind France and Germany.

Jean-Pierre Contzen, Director-General of the European community's Joint Research Center, provides a model for how clarification takes place in the idea of "subsidiarity." A nation, he says,

> initially strives to handle all projects at the lowest possible government level. Programs then pass upward from provincial or regional to national to multi-national and international jurisdictions. Thus, Italy's space agency ASI pursues with other European nations on the *Columbus* International Space Station platform, which in turn, involves the US, Japan, and Canada. Each stage presents trade-offs between cooperation and competition. Competition is often necessary to spur funding, and a national team may provide the most responsible project management. However, large-scale programs almost automatically require cooperation. (16)

Specifically, the demise of the Former Soviet Union (FSU) has opened doors to opportunities that were never perceivable. The rush is on to harvest new ventures. The appointment of a new position, Associate Administrator for Russian Programs, in the NASA Office of the Administrator is just an indication of the active pursuit in these endeavors. There is no procrastination in fostering the developments.

Two Russian cosmonauts (Sergei K. Krikalev and Colonel Vladimir G. Titov) began training in October, 1992, at Johnson Space Center. They familarization-trained on US space shuttle systems, flight operations, and manifest payload procedures. As one of the first elements in the Implementing Agreement on NASA/RSA (Russian Space Agency) Cooperation in Human Space Flight, STS-60 (February 1994) marked the first launch of a Russian citizen aboard an American spacecraft, carrying Sergei Krikalev and renewing US-Russian space cooperation. A major mission accomplishment was the successful deployment of six small metal spheres from the Orbital Debris Radar Calibration Spheres (ODERACS) experiment used in calibrating radars that track orbital debris. More recent (February 1995) was the launch of STS-63 with Vladimir Titov, who was able to fly right up to his prior home on the *Mir* in a simulated docking attempt.

These endeavors place into action the foundation for future cooperative programs in other areas. One could be the development of a joint missile defense system. Such a plan is in discussion now. Named the Global Protection System (GPS), the program could be the first time FSU military fall under US command.

Also, the Spectrum mission series call for Russian spacecraft loaded with American instruments to take flight in 1995. Alan N. Bunner, chief of NASA's High Energy Astrophysics Branch in Washington, DC, proclaims the program a "marriage of what each one (country) does the best. The Russians get state-of-the-art instrumentation on their satellites, and we get a free ride into space—saving American taxpayers millions of dollars." (13:54) In short, "unhampered by the seemingly interminable delays that plague our space program, the Soviets catapult satellites into space with a metronomic consistency that amazes their American counterparts." Marsa proceeds, "The United States and other Western nations, on the other hand, excel in making the precisely calibrated hardware to gather data on astronomy and planetary science that can also withstand the rigors of space flight." (13:54)

There have been discussions to use a *Soyuz* spacecraft in the interim as a rescue craft for the International Space Station. Our launch vehicles just do not have the necessary capacities and processing times are too long, while the impressive performance of the Russian space tug, *Salyut FGB*, has been widely demonstrated.

Application of nuclear propulsion, using current Russian reactors, could give the Mars missions a shot in the arm. Travel time to the planet could conceivably be reduced from one year to less than three months.

Other recent international events:

- NASA and the National Space Agency of Ukraine (NSAU) came to agreement in July of 1994 to develop programs together in the areas of remote sensing and earth sciences, telemedicine, space biology, space welding, advanced concepts and technology, and student and scientist exchanges. The Paton Institute in Kiev is a world leader in space welding technologies.
- European astronaut, Ulf Merbold, was the first ESA astronaut aboard the Russian Space Station last October 6th.
- Norman Thagard and Bonnie Dunbar trained in Star City, Russia to spend time on the *Mir* Space Station. Thagard is now the first American to ride aboard a Russian rocket.
- The objective of STS-72 this fall is to retrieve a science satellite that will be launched from a Japanese H-2 rocket. The Japanese National Space Development Agency mission specialist, Koichi Wakata, will be a crew member aboard the US space shuttle.
- Canada is proceeding with their commitment to develop the Mobile Servicing System for the International Space Station.

Russian Concerns

President Yeltsin formally established the Russian Space Agency, which would have similar functions as NASA in managing civilian space programs. However, there are funding problems and difficulties in the military-to-civilian transition. Internal disputes are even causing some elements to bill others for services in the same program. (1)

This is only one example of the varied reasons the skeptics don't want the US to become dependent on the FSU. There are differences to be overcome in living conditions, working conditions, and cultural and language barriers. The long-term stability of the government and free-market reforms is uncertain. In addition, the organizers of the Russian space program are primarily from the areas responsible for generating their war-making capabilities. Few people would like to be blamed for strengthening their industrial and technical base, only to be used militarily by a future, hostile government. Much of the concern stems from "lingering suspicions from decades of opposition." (12)

Domestically, workers in the space industry are distressed at losing jobs to Russians. Likewise, Europe and Japan are wondering how they will influence future developments if collaboration between the two space superpowers do not involve them.

We must remember, cooperation may be the only way to meet goals of such elephantine proportions. The objective is to blend our technological capabilities, not just sell/purchase equipment and services. Russians excel in propulsion and some materials and structures, while we have more expertise in electronics,

computer hardware, and software. The most likely steps will be to start small and slowly increase integration of Russian-US programs. As trust and understanding develop, it will become an easier process to incorporate.

Although the removal of the Iron Curtain has led to many new possibilities, there are some negative aspects. Communism fostered development of brilliant personnel, and its fall has left a void in cultivating a new generation of workers. Although they were often portrayed as technologically inferior, the fact is Russians excelled in specialized areas involving computer software, metallurgy, high-energy physics, and synthetic chemistry. Knowledge in theoretical physics and applied mathematics, where only a sharp mind and pencil are required, was matched by few.

As an aid to help prevent the collapse of Russia's technological and scientific infrastructure, Congress has authorized $400 million to dismantle their nuclear build-up. George Soros, American financier, has donated an additional $100 million to aid scientific institutions in equipment and research. (13:52) In addition, several scientific and government organizations are assisting in collaborative research programs.

American corporations are entering into joint ventures to tap some of the available talent. In the years 1991-1993 alone, around 8,000 Soviet scientists came to New York. At least 500 members of the Russian Academy of Sciences have emigrated. When truck drivers earn more than electrical engineers, careers will change and trained scientists will leave. In Moscow, potential Nobel Prize winners are already driving cabs. The Association of Engineers and Scientists for New Americans (formed in New York, 1981) show recent figures of 45,000-50,000 FSU refugees entered the US from 1991-1994. On average, 70% of that total have higher education with 9% of these carrying PhD equivalents or higher. This is not even counting the 2,000-3,000 immigrants per year.

To make matters increasingly urgent, one must remember that the half-life of technical knowledge expertise is growing exponentially short. As engineers concentrate on survival, and not staying up-to-date in their career, the tougher it becomes for them to get involved again. "If Russia does not keep its most productive scientific groups intact, it will be disastrous Everything depends on their becoming economically viable," exclaims Nobel Laureate physicist and former president of the American Association for the Advancement of Science (AAAS), Leon Lederman. (13:54)

Hungry engineers looking for freelance work can be a dangerous thing. Flooding the open market with rocket scientists and nuclear physicists could play right into a hostile leader's hands. It is already estimated that several new countries could have the capability to build intercontinental ballistic missiles capable of striking the US with nuclear weapons by the middle-to-late 1990s. This is a central factor in establishing the International Science and Technology Center in Moscow. Its role will be to fund civilian projects for former weapons scientists (backed by the United States, the European community, Japan, and Russia) allowing them to remain in their country.

Safety Standards

One major difference in Eastern and Western space programs is in the area of safety. Frankly, there is not even a viable safety program in the Russian arsenal. Cosmodrome visitors have seen such absurd things as vital interconnects held together with nothing but duct tape. Also, range considerations appear to have been overlooked.

Throughout its flight to outer space, a spaceship can shed up to 98% of its weight. Most of it is in fuel expenditure, but some hardware does tumble back down to earth. In Western countries, impact zones are placed in oceans which capture the falling rocket stages. However, Russian launch facilities rain debris in the center of the continent. These locations are supposedly uninhabited, but recent protests from Kazakhstan residents have disproved the idea. Operations from the nearby Baikonur cosmodrome have left residents with fuel residue and metal shrapnel that is preventing livestock from grazing and hay from being harvested. Damage is estimated at tens of millions of rubles per year and has harmed millions of hectares.

North of Moscow, launches from Plesetsk have possibly affected reindeer herds by leaving sharp objects laying around forest trails. Concern is expressed near the Arctic Ocean in the Nenets region about dangers involved with falling objects over high-pressure natural-gas pipelines. (14) The Uvatskiy Region local government, near Plesetsk, went so far as to vote for a complete ban on any space activities over their territory. Without a strong police force anymore, control over the citizens' outbursts is gone. Lawsuits are being filed. The outcome will have to be dealt with, and, regardless, improved safety measures must be instituted.

Systemic Look at the Environment

There are innumerable opportunities in which to apply space technology. In a global sense, the **International Geosphere-Biosphere Programme (IGBP)** will attempt to coordinate scientific studies concerning our planet. The goal is to improve knowledge of our global environment, and develop predictor models of damage caused from human or natural causes.

Since most large environmental worries are global problems, they naturally spur global involvement. Many current programs have been doing so for years, and the extent and variety among them is surprising. Some of the following international successes are solid examples for future initiations to follow:

- The **Enhanced Greenhouse Effect Detection Project**, led by the United States' NASA, will use space data to determine how the growing concentration of "greenhouse" gases in the atmosphere may raise the earth's temperature.
- The **Polar Stratospheric Ozone Project**, jointly led by NASA and Germany, aims to improve predictions of the effects of natural and man-made gas emissions on the ozone layer by analyzing data from space observation and ground-based balloon and aircraft flights.
- The **Global Consequences of Land Cover Change Project**, headed by Australia, France, and the Former Soviet Union, seeks to use space measurements to predict the global consequences of changes in land cover in selected regions of the world and the impact of such changes.
- The **World Forest Watch Project**, jointly led by Brazil and the European Community, is using remote sensing to study tropical and temperate forests worldwide, including a global survey of forest fires. Its major goal is to determine the rate of deforestation in Brazilian Amazonia.
- The objective of the **Polar Ice Extent Project**, led by the ESA and Japan, is to provide space-borne data on the extent of seasonal changes in the Arctic and Antarctic sea ice and large-scale ice motion at the poles.
- Canada and the European Community are leading the **Productivity of Global Oceans Project** to generate and

distribute an archive of maps showing, for example, the distribution of phytoplankton—the microscopic, drifting organisms that consume carbon as part of a cycle which influences the level of carbon dioxide in the atmosphere.

- The **Ocean Variability and Climate Project**, headed by the ESA, seeks to improve understanding of the climatic impact of oceanic phenomena using various satellite data.
- The **Sea Surface Temperature Project**, led by Japan and the United Kingdom, demonstrates fisheries, weather forecasting, climate monitoring, and other applications for satellite measurements of sea surface temperatures.
- The International Astronautical Federation, through the **Space and Disaster Prevention, Preparedness and Relief Project**, seeks to use meteorological, communications, remote sensing, and other satellites in orbit to warn of disasters and help in relief efforts.
- The **Global Satellite Image Mapping Project**, led by the Austrian Space Agency, is to produce high resolution maps of and data on the solid earth for scientific and educational purposes.
- The **Global Change Encyclopedia Project**, headed by Canada, is to develop an electronic tool consisting of computer data files for monitoring environmental phenomena.
- Austria is preparing a **Global Change Atlas** which will map satellite and other data on global environmental change.
- The United Kingdom and Germany are heading the **Global Change Video Project** which will develop photo-realistic images of satellite data to illustrate how the land surface of the earth has changed over the last two decades.

Mission to Planet Earth

In America, 11 federal agencies have been tasked with developing and evaluating solutions to the environmental problems of our planet. They are involved in what has been designated as the **United States Global Change Research Program (USGCRP)**. Of course, when studying a system as large as an entire planet, examining the "big picture" all at once can only be possible from a new frame of reference. It is this very concept that drives USGCRP participation from NASA's largest environmental project, the **Earth Observing System (EOS)**, also referred to as "Mission to Planet Earth." The EOS budget is currently $11 billion spread over an eight-year period. Its importance is emphasized by noting Europe and Japan's simultaneous endeavor to develop their own ecological satellites.

There is some opposition to the plan. A few earth and ocean scientists believe we should make better use of our land and sea-based observation programs before spending such huge sums of money on a new program. Another factor is that NASA is already committed to more missions than it can realistically pay for, especially considering the budget-reducing environment we are in. Once again, logistics specialists could be the key to help cut life-cycle costs of new and even on-going projects.

The original plans called for two huge, polar-orbiting platforms dubbed EOS-A and EOS-B. Instruments from several nations would be aboard, which would have to be replaced two times during the fifteen-year experiment. Concerns that the platforms are too complex and estimates of technical failures consistently plagued the design. In addition, there was a lack of flexibility and acquisition costs were too high. Unfortunately, budget reductions may now cause reliance on European and/or Japanese instruments which are not as capable. Size and weight constraints of launch vehicles were also limitations.

"Like your body, the Earth is very complex. If you've got something wrong with you, you can't just take your temperature, you've got to do a whole bunch of other things," says Jerry Madden, EOS Project Manager. In the same way, "you've got to treat the whole Earth as a system . . . and you can't do that with one small probe." (10:44) Many questions remain to be answered concerning the earth's illnesses. Must we reduce carbon dioxide emissions? What is the effect of global warming and will it impact on ocean currents? How will more powerful weather phenomena change our world? EOS hopes to answer some of these questions by tracking environmental changes from 1998-2017. The changes are to be monitored from the following satellites:

EOS-AM1 (launch date: June 1998) - Will chart different vegetation properties, size and location of clouds, carbon monoxide levels, and total heat entering and leaving the atmosphere by measuring many different radiation wavelengths. It will cross the equator in the morning. **EOS-PM1** (launch date: 2000) - Will perform similar functions to the AM1, with the addition of temperature, pressure, and humidity measurements in the lower atmosphere. It will cross the equator in the afternoon, when solar heating is at a maximum. **AERO** (launch date: 2000) - Will measure long-term trends in such stratospheric gases as ozone and water vapor. It will carry the Stratospheric Aerosol & Gas Experiment III (SAGE III) to record the mixing of aerosol molecules. **ALT** (launch date: 2002) - Will chart precise ocean, ice, and land surface topography by timing how long it takes for laser and radar pulses emitted to be reflected and returned. Altimetry instruments will also record the amount of polar ice cover. **CHEM** (launch date: 2002) - Will use several instruments to measure atmospheric chemistry and levels of gases associated with ozone loss, acid rain, green-house warming, and ocean-surface winds. (5) **COLOR** (launch date: 1998) has just been scrapped; however, there has been an addition to the program of three others: **LASER ALT** (launch date: 2003), **AM2** (launch date: 2004) and **PM2** (launch date: 2006).

The new plans call for use of the five satellites above which will be placed into orbit with Pegasus and Delta 2 or Atlas 2AS boosters. There will also be at least 16 "Earth Probes" deployed throughout the program. The first one was launched in 1991. It was an early cooperation success in the joint **Soviet-American Total Ozone Mapping Spectrometer/Meteor Mission**. This satellite was recently deactivated when its useful life was up and data collection complete.

A vital part of the program (another ILS element: Computer Resources) is still to be fully developed. NASA must build the largest non-military computer database to handle the volumes of information generated. A primary stumbling block in the use of space data by the world science community has been the inconsistency of procedures and data formats. (17) Deciding on application of an international Continuous Acquisition and Life Cycle Support (CALS) standard would greatly benefit the situation. Furthermore, a UN progress report (A/AC.105/487) asserts that the international science community's greatest challenge in using space data is ensuring that they receive consistent, standardized data from a myriad of satellites in an uninterrupted fashion to accurately document global changes.

The **Earth Observing System Data Information System (EOSDIS)** will eventually receive and process up to 2 terabytes (2 trillion) of data each day. This is equivalent to the current amount of data stored in the US Library of Congress. (5) Since all of the information in the world is worthless unless it can be processed into a usable format, seven centers around the US will

transform the data into products that scientists may use worldwide. Version 0 of EOSDIS went into early operations in 1994 to begin processing data from the Earth Probes. The Global Change Data Center located at the Goddard Space Flight Center, Greenbelt, Maryland, is now working on Version 1.

Array of United Nations Efforts

As our world becomes a closer-knit community, we must share ways to improve living conditions for everyone. If we are to consider the entire global population, there is no better place to start than in space. That is the ultimate objective of several world-wide organizations.

The International Geophysical Year (1957) saw the birth of the space age with the Soviet launch of *Sputnik 1*. To celebrate the event, along with the 500th anniversary of Columbus, 1992 was proclaimed to be the International Space Year. Our goal is to "highlight the importance of understanding the Earth as a single, complex, interdependent system and to stress the unique role that space science and technology can play in promoting that understanding," stated Secretary-General Boutros-Ghali to the World Space Congress (WSC) in Washington, DC. (17) The WSC was a nine-day conference (beginning August 28, 1992) with more than 3,000 international scientists, engineers, and policy makers in attendance.

1992 was also the tenth anniversary of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, named UNISPACE II. Conference negotiations were designed to consider the benefits of new technology developments and applications for all countries. A third UNISPACE will assess the following programs in the mid-1990s:

- The **Food and Agriculture Organization of the UN** has been in the forefront in applying space technologies since the establishment of its Remote Sensing Centre in Rome in 1980.
- The **International Maritime Organization** depends on satellite communications systems to aid navigation and provide distress alerts from ships as part of its global system for maritime search and rescue.
- The **International Telecommunication Union** provides technical expertise and other assistance in developing satellite communication systems.
- The **UN Development Programme**, which has funded hundreds of space application projects since 1964, uses satellite imagery to report on and forecast the movement of desert locust swarms.
- The **UN Disaster Relief Office** is conducting field trials of a portable satellite transmitter which would allow a relief officer on site in a disaster area to transmit detailed information about priority relief requirements.
- The **UN Environment Programme** in cooperation with the **UN Centre for Human Settlements (Habitat)** is using high-resolution satellite images to produce data for urban planning and management in cities in the developing world, such as Manila, Philippines and Dar es Salaam, Tanzania.
- The **UN Educational, Scientific and Cultural Organization** for over two decades has conducted projects in the use of space community systems for education, information, culture, and development.
- The **World Health Organization** uses satellite images to improve research and control of vector-borne diseases in tropical countries.
- The **World Meteorological Organization**, which has been tracking weather via satellite for the past 25 years through its **World Weather Watch Programme** utilizes meteorological satellites to post warnings of tropical cyclones. (17)

Space Waste

When it comes to environmental problems, the "out-of-sight, out-of-mind" belief is moot. Alarmingly, pollution is even beginning to have a profound impact in space. Rocket boosters, payloads, spacecraft, and shrouds are but a few types of litter beginning to clutter up orbits. It has been US policy since 1989 to minimize space waste and are calling for other countries to comply.

There is no official definition of what constitutes space debris, and any controls over it is strictly on a voluntary basis.

> If a nation chooses to develop an orbital scrubber, some device which could vaporize or collect debris in Low Earth Orbit, could it demand payment for services rendered from other spacefaring nations? Or, if a nation's spacecraft were to be destroyed by debris, should there be some compensation fund, funded by all spacefaring nations, available to cover the loss? (7)

The UN must develop a treaty concerning this issue, but it is not even on a near-term agenda.

The Russian Defense Ministry proposed that a joint space tracking/reentry test be performed with Russian military space forces and the United States Space Command (USSPACECOM). (1:19) They would like to use US facilities to monitor two 172-pound solid metal spheres as they gradually decay from orbit. Trading tracking data would allow updates to reentry models and better understanding of how the upper atmosphere affects orbital decay.

Twenty-four hours each day, the USSPACECOM watches over 6,700 pieces of junk. That figure comes only from objects we can track at altitudes above 800 kilometers. That is the approximate limit to the natural cleansing ability of the atmosphere. Any object less than ten centimeters (around softball size) is too small to be "seen," making the actual amount far greater.

Data already supports the theory that in the next few decades, chain reactions of space debris striking each other will multiply to an unacceptable level. Garbage from operations is already increasing at approximately 5% per year.

In support of a solution, the first space debris test was initiated January 10, 1992. The study, dubbed the Satellite Orbital-Debris Characterization Impact Test (SOCIT), involved firing a 150-gram aluminum sphere at 6 kilometers/second into the US Navy OSCAR 22 satellite. (11:8) The satellite's destruction was filmed using high-speed photography. All fragments were captured and will be analyzed at a later date.

Bringing the problem closer to home, in a 1989 flight, the Space Shuttle *Challenger* was hit by a small object. It created enough damage to require complete replacement of a glass panel in the forward fuselage. Learning that the orbiter has a one-in-thirty chance of hitting some form of space junk, Andrew Petro, an engineer at Johnson Space Center, decided to try his hand at

(Continued on bottom of page 25)

Sustaining Space Systems for Strategic and Theater Operations

Wally McCoy

Our Desert Storm experience in the tactical utility of Department of Defense (DOD) space vehicles demonstrated that DOD's investment in space technology can provide a significant military advantage during times of crisis and war. The satellites that gave us such marvelous intelligence in locating, tracking, and enabling the successful attack of key targets resulted in a spectacular military success. However, without an on-orbit servicing capability, the fuel consumed to maneuver these satellites into position over the battlefield shortened their useful life by as much as two years.

During the 1970's and 1980's, the Air Force aggressively pursued an on-orbit support capability to support and maintain it's space-based assets. However, in the early 1990's, budgetary and political priorities canceled the programs that would have made this a reality.

Realizing that a future decision may be made to reinvestigate on-orbit support, the United States Space Command (USSPACECOM) sponsored a study to document efforts undertaken by the Air Force during the 1970's and 1980's in developing strategies and actions to achieve certain tenets of on-orbit support. The study represents an attempt to gather, review, summarize, and archive the most important research performed during this period. It will serve as a historical perspective upon which to base future research and development activities. This paper presents an overview of that study.

Introduction

From the 1960's through the 1980's, on-orbit support concepts and analytical tools were developed by the National Aeronautics and Space Administration (NASA) and DOD to evaluate the potential for on-orbit servicing of space systems. Many studies were performed to assess the technical feasibility and cost effectiveness of accomplishing satellite maintenance and servicing operations in space. In general, these studies concluded on-orbit maintenance and servicing is technically feasible and that no technology breakthroughs are required. Depending on constellation size, location, and on-orbit support concept utilized in the analysis, these studies demonstrated a potential life cycle cost savings range of 10% to 50% through the employment of an on-obit support strategy.

With the cancellation of the Orbital Maneuvering Vehicle (OMV) and the Satellite Servicer System Flight Demonstration (SSS/FD) programs, the Air Force has not played an advocacy role or demonstrated an interest in developing an on-orbit support capability. NASA, on the other hand, has continued to develop an on-orbit support capability that was again demonstrated during the *Hubble* Space Telescope (HST) repair mission.

Background

The March 1992 update of Air Force Manual (AFM) 1-1, *Basic Aerospace Doctrine*, addresses the increasing role of space assets in supporting and sustaining space operations. The document states, in part, that sustained employment of space assets must be planned for to ensure sufficient replenishment of space-based resources is achievable when adapting to changes in circumstances dictated by mission operations. The doctrine clearly states that on-orbit support for space assets can be crucial to campaign success and that flexibility in space employment will require a combination of reserve platforms and launch systems, development of on-orbit spares, and the employment of both robotic and manned space platforms. Further, it cites that a space platform's effectiveness can be significantly expanded by providing vehicles and crews to repair or modify the platform, service it, or restock consumables such as fuel. (2)

USSPACECOM's December 1990 *Assured Mission Support Space Architecture* (*AMSSA*) focused upon the following key objectives:

- Robustness.
- Flexibility.
- Survivability.
- Sustainability.
- Availability.
- Affordability.
- Normalization of support to space assets.
- Supportability of deployed space systems. (3)

To assure the United States has and retains ready access to space during peacetime and during times of increased global and regional tensions, the AMSSA study identified six specific initiatives, referred to as the "Big Six," that must be improved and/or implemented:

(1) Communications.

(2) Navigation.

(3) Launch Capability.

(4) Command and Control.

(5) Satellite Control.

(6) Integrated Logistics Support of Space Systems. (3)

It is the latter that addresses several tenets of the on-orbit support doctrine contained in AFM 1-1.

Feasibility of On-Orbit Support

Since the 1950's, man has been launching and operating satellites in space. These spacecraft have had varied missions such as communications, navigational aids, experiments, weather, surveillance, and other military missions. The concept of on-orbit support dates from the first satellite failure. In the early days of space flight, the first concern was to merely get the satellite into orbit. Once that barrier was passed and orbiting satellites began returning data, interest turned toward increasing satellite performance.

The strategy for maintenance of these spacecraft was reconfiguration by telemetry to correct individual element failures and abandonment after critical failure. Abandoned satellites are usually replaced with either a new satellite launched from the ground or a pre-positioned on-orbit replacement satellite. The concept of abandoning large and expensive satellites after failure is counterproductive in a time of reduced defense budgets.

During the 1980's, in partnership with private industry, NASA developed the Multimission Modular Spacecraft (MMS) design, a reusable bus containing three replaceable boxes that control spacecraft power, data handling, and attitude. Solar Max, launched on 14 February 1980, was the first satellite to use the new design. After nine months of operation, fuses failed in the attitude control subsystem module, rendering four of its seven instruments useless and compromising operations of the remaining three. In April 1994, the space shuttle *Challenger* was launched on a mission to capture and repair Solar Max. Although many unexpected difficulties arose during this mission, Solar Max was restored to service and a new era in orbital servicing and repair was launched. This mission provided the experience and know-how necessary to capture and launch into their proper orbits the Palapa-B and Westar-6 satellites later the same year. These satellites had been placed into a wrong orbit due to a failure in their booster stage.

Also, during this period, NASA designed and built the *Hubble* Space Telescope (HST) specifically to be maintained on-orbit by astronauts through extravehicular activity (EVA). Should the space station become a reality, it is intended to be maintained on-orbit through a combination of EVA and the use of sophisticated robotics.

By the end of the 1980's, numerous DOD and NASA studies and design concepts resulted in the establishment of a clear requirement for an on-orbit support capability. As a result, NASA and the Strategic Defense Initiative Organization (SDIO) formed a partnership to develop a Satellite Servicer System Flight Demonstration (SSS/FD) program. This was a joint effort to initiate a program to design, develop, and demonstrate a satellite servicing capability. A series of three flight demonstrations scheduled for 1993 through 1995 was planned.

During the same timeframe, SDIO formulated a Space Assets Support Systems (SASS) implementation plan based upon existing and near-term technologies and capabilities. The plan, essentially a preliminary acquisition program plan, recommended that a SASS system program office be established to manage the design, development, and deployment of the SASS.

Unfortunately, national political and budgetary considerations forced the premature cancellation of the SSS/FD program and eliminated an opportunity to develop and demonstrate a very feasible, cost-effective alternative to the expensive "abandon-and-replace" concept currently used when spacecraft encounter failures, critical anomalies, or even fuel shortages.

In addition to the satellites that were diverted from other strategic surveillance missions during Desert Storm, there are several communications satellites currently on-orbit that have drifted slightly out of their intended orbits. There is insufficient fuel remaining in these satellites to maneuver them back into the proper orbit for maximum utilization of their capabilities. The capability to refuel these satellites on-orbit would provide military commanders the flexibility to reposition satellites to meet theater contingency requirements without significantly affecting the lifetime of the satellite. Additionally, survivability of the spacecraft could also be enhanced by an assured refueling capability in extending the satellite's ability to perform elusive and evasive maneuvers to counter threats.

NASA and DOD currently cosponsor an active committee under the American Institute of Aeronautics and Astronautics (AIAA) that is developing necessary standards with the assistance of industry that, if implemented on future space vehicles or during block upgrades to existing space systems, could quickly produce the design and employment of on-orbit refueling ports or receptacles aboard many space vehicles to facilitate the safe, on-orbit transfer of fuel.

Conclusions

Many studies have been conducted which identified potential cost savings and other benefits to be realized through on-orbit support of space systems. There are wide differences in the amount of savings projected, sometimes even for the same space system, and in the method of measuring the savings. The differences are due to the varied methodologies, assumptions, and parameters used by the organizations conducting the studies. In addition to the potential cost savings, these studies have demonstrated that on-orbit support provides service life extension through a refueling capability, the capability to infuse new technology through the replacement of orbital replaceable units, and the ability to upgrade a system to meet expanded threats.

There does not appear to be any technological roadblock to on-orbit servicing. The driving technologies have been identified. An increased capability to service and maintain spacecraft on-orbit will continue to evolve through NASA efforts and independent research and development efforts of the aerospace industry.

All of the studies examined concluded that there are several support capability needs which are key to the success of assuring mission support, and that these needs require positive commitment from senior Air Force and DOD decision makers. Most notable of these are the normalization of support of DOD space systems, modularity and standardization in space vehicle design, expanding DOD organic support, and the pursuit of on-orbit servicing capabilities to enhance satellite endurance.

References

1. United States Space Command. *Sustaining Space Systems for Strategic and Theater Operations Study*, 17 Sep 93.
2. Air Force Manual 1-1, *Basic Aerospace Doctrine*, Mar 92.
3. United States Space Command. *Assured Mission Support Space Architecture*, Dec 1990.

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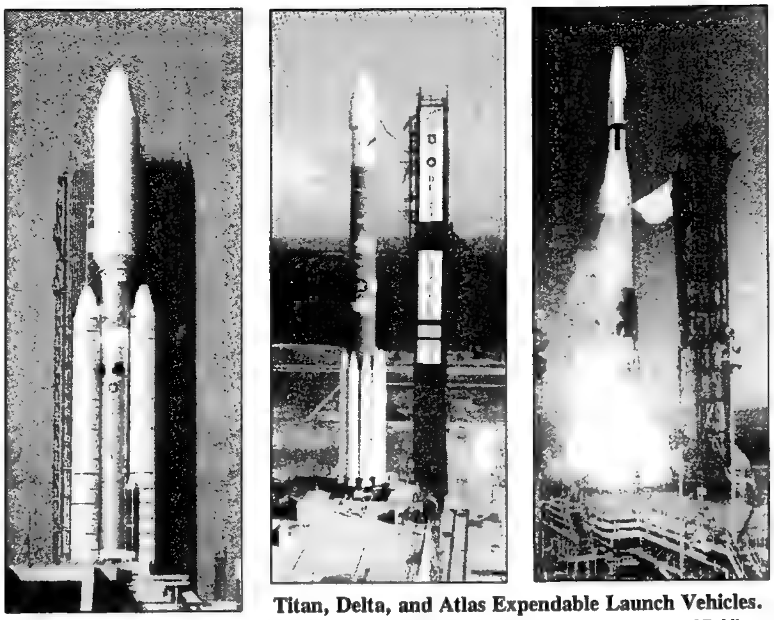
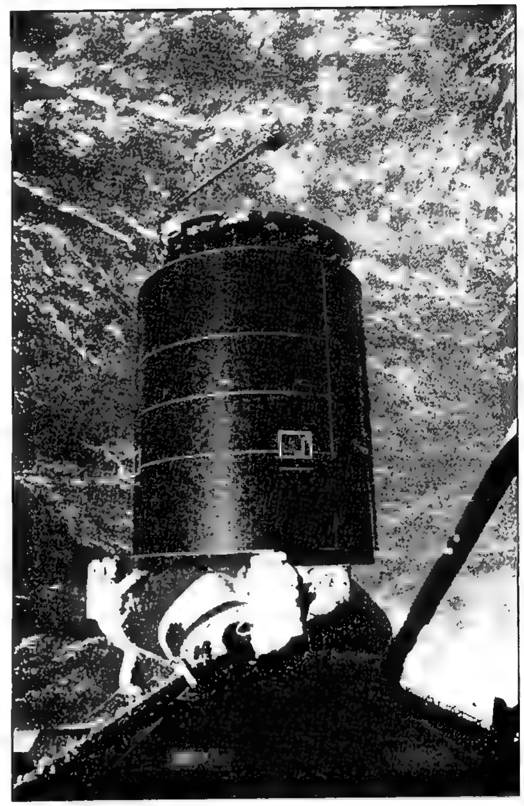
Best Article Written by a Junior Officer

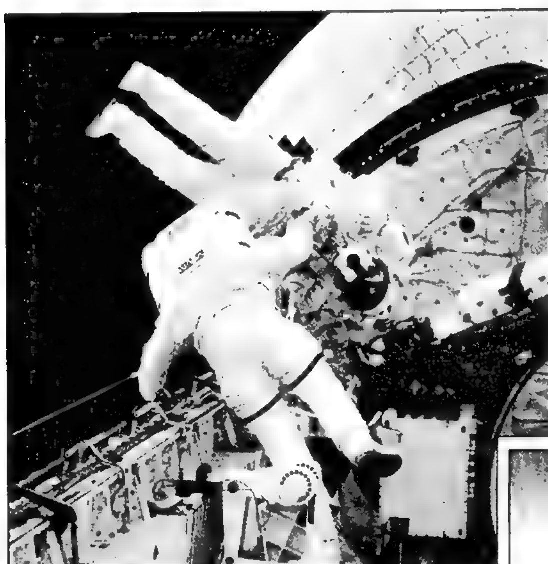
An Executive Panel of the Montgomery, Alabama Chapter of the Society of Logistics Engineers (SOLE) has selected "Activity Based Costing: Accounting Information to Measure, Manage, and Improve Activities and Processes" (Fall 1994), written by Captains Robert W. Callahan, USAF, and Daniel A. Marion, Jr., USAF, in collaboration with Major Terrance L. Pohlen, USAF, as the best *AFJL* article written by a junior officer(s) for FY94.



Titan, Delta, and Atlas Expendable Launch Vehicles.
(USAF Photos, Courtesy of HQ Air Force Space Command Public Affairs and Air University Press)

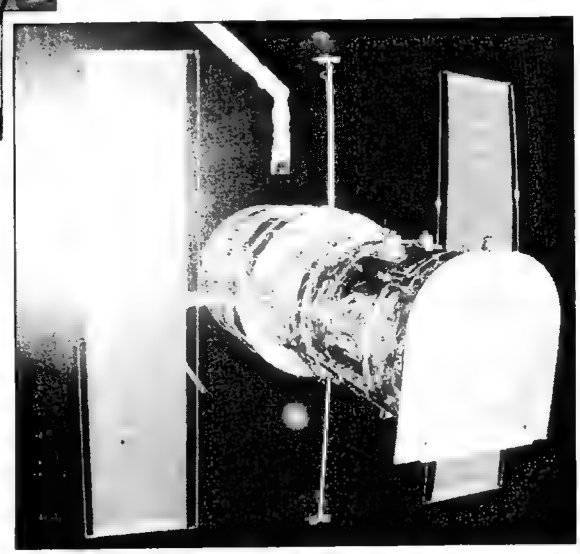


***Hubble* Space Telescope Deployment.**
(NASA Photo, Courtesy of United States Space Foundation)

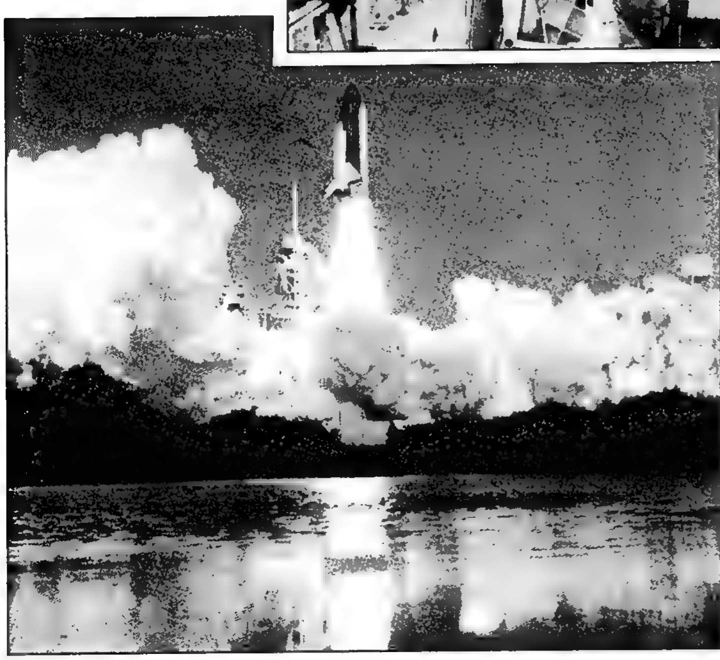


***Endeavour's* Astronauts Gregory Harbaugh and Mario Runco, Jr. Evaluating Ability to Move About with a "Bulky" Object in Hand.**

(NASA Photo, Courtesy of HQ Air Force Space Command Public Affairs)



Successful Capture of the Intelsat VI Satellite.
(NASA Photo, Courtesy of HQ Air Force Space Command Public Affairs)



Liftoff of Space Shuttle *Columbia*.
(NASA Photo, Courtesy of HQ Air Force Space Command Public Affairs)

Career and Personnel Information

Civilian Career Management

Logistics Civilian Career Enhancement Program (LCCEP) Whole Person Score (WPS)

Career management responsibility begins with the employee. Career achievements are reflected in LCCEP's whole person score (WPS). The WPS category over which employees have the most control is education and training. Individuals may enhance their WPS by enrolling in college courses, participating in professional military education, taking advantage of professional civilian education opportunities, and obtaining certification as a Certified Professional Logistician (CPL).

The LCCEP uses the WPS to identify the competitiveness of registrants for promotion and training opportunities. Each LCCEP registrant's WPS is computed automatically via the Defense Civilian Personnel Data System (DPCDS). The LCCEP WPS is divided into four categories: (1) Professional Experience, (2) Education and Training, (3) Performance Appraisal, and (4) Assessment (Interview and Behavior Inventory). The latter category is not applicable to GS-12 and below registrants nor is it applicable to GS-15 registrants.

This article focuses on the WPS Education and Training category. The maximum number of points attainable is 80. This category is subdivided into four elements:

ELEMENTS	MAXIMUM POINTS
Formal Education	48
Professional Military Education	12
Professional Civilian Education	12
Certified Professional Logistician	8
	80

Formal Education - A maximum of 48 points can be awarded in this element. Points are awarded for different levels of achievement indicated below. To help registrants achieve educational goals, tuition assistance is available through LCCEP for registrants in grades GS-11 through GS-15 (beginning with GS-7 for registrants in transportation occupational series) with five years of Federal Civil Service and recorded semester/quarter hours which equal at least two years of college. To apply for tuition assistance, a registrant must submit a DD Form 1556, Request for Training, to the immediate supervisor as outlined in AFR 40-110, Vol IV (soon to be replaced by AFMAN 36-606, Chapter 12). The different levels of achievement for which credit is allowed are:

LEVELS OF ACHIEVEMENT	POINTS
One year college	6
Two years college	12
Associate's degree	13
Three years college	19
Four years college	24
Bachelor's degree	36
Master's degree	48

Professional Military Education - A maximum of 6 points for grades GS-9 through GS-11, and 12 points for grades GS-12 through GS-15 can be earned in this element. Registrants can earn these points by completing the course by correspondence, in seminar, or in residence. Correspondence courses for the Air Force schools are accessible to all registrants. Seminars are available in most locations. Registrants can contact their servicing Education and Training Office for information on correspondence courses and seminars. To be considered for in-residence courses, this training must be recorded on the registrant's Career Enhancement Plan (CEP) as required by AFR 40-110, Vol IV. Air Force-wide competition for limited Air Force civilian quotas is conducted annually. Creditable courses are listed below:

COURSE TITLE	ELIGIBILITY	POINTS
Squadron Officer School	GS-9 - 12	6
Armed Forces Staff College	GS-12 - 15	12
Air Command and Staff College	GS-12 - 15	12
Naval Command and Staff College	GS-12 - 15	12
Army Command/General Staff College	GS-12 - 15	12
Air War College	GS-14 - 15	12
Navy War College	GS-14 - 15	12
Army War College	GS-14 - 15	12
National War College	GS-14 - 15	12
Industrial College of the Armed Forces	GS-14 - 15	12

Professional Civilian Education - A maximum of 12 points can be earned in this element at grades GS-13 through GS-14. These training events are available through Air Force-wide competition. For a registrant to receive consideration, these opportunities must be recorded on their CEP as required by AFR 40-110, Vol IV. Consult the annual Air Force Career Programs Training Guide for eligibility requirements for each program. The creditable courses in this element are:

COURSE TITLE	ELIGIBILITY	POINTS
LEGIS Fellows Program	GS-14 - 15	12
Woodrow Wilson School of Public & International Affairs - Princeton	GS-13 - 15	12
Alfred P. Sloan Fellows School of Management - MIT	GS-13 - 15	12
Congressional Fellowship	GS-13 - 15	12
School of Public Administration - University of Southern California	GS-13 - 15	12
John F. Kennedy School of Government - Harvard	GS-13 - 15	12
Stanford Sloan Fellowship	GS-13 - 15	12

Certified Professional Logistician - A maximum of 8 points can be awarded in this element. Certification requires successful completion of an eight-hour examination conducted by the Society of Logistics Engineers (SOLE). To apply for the examination, contact the local chapter of SOLE or the SOLE Headquarters at commercial telephone number (301) 459-8446 or the following address:

Society of Logistics Engineers
Attn: Chairman, CPL-QRB
8100 Professional Place, Suite 211
New Carrollton, MD 20785 USA

Annually, registrants must carefully review their individual personnel records for accuracy and proper WPS credit. The responsibility for complete and accurate personnel records rests with the each registrant. If registrants have completed education or training since the date shown on their most recent career brief and have not submitted documentation to have records updated, they should do so now. Registrants should contact their local Central Personnel Flight (CCPF) to update records. (Fred Kendall, AFCPMC/DPCLO, DSN 487-4087)

(Continued on top of page 41)

This is the second of the two-part article on Activity Based Costing (ABC). The first article appearing in the Fall 1994 issue provided a basic introduction to ABC.

Activity Based Costing: Applications in Military and Business Logistics

Major Terrance L. Pohlen, USAF, PhD
Captain Robert W. Callahan, USAF
Captain Daniel A. Marion, Jr., USAF

Activity based costing (ABC) has only recently emerged as a technique for obtaining more accurate cost information to support logistics decision making. During the past decade, ABC applications have concentrated on costing manufacturing activities and resources to more accurately determine product costs. However, many logistics managers have recognized that logistics decision making could also benefit from more accurate cost information. As a result, a limited number of military and business organizations have examined and implemented ABC. This article explores 12 applications of ABC within military and business logistics. The experiences of these organizations suggest that ABC *does* more accurately cost the logistics activities they perform and leads to a better understanding of how customer requirements drive logistics costs.

Activity Based Costing

ABC is a technique to more accurately assign the direct and indirect costs to the activities and products or services which consume an organization's resources. ABC uses multiple cost drivers to assign indirect costs to the products or services consuming an organization's resources. The tracing of costs follows a two-stage process. The first stage assigns resource costs based on the amount of each resource consumed by an activity. The second stage assigns activity costs to the products or services consuming the activities based on actual consumption. Figure 1 illustrates the two-stage assignment process. (1)

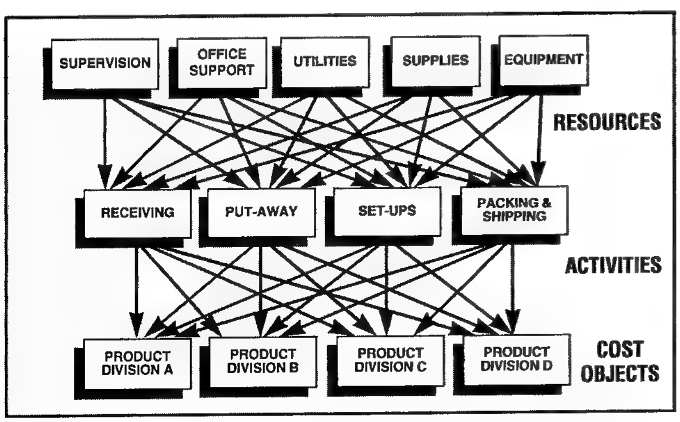


Figure 1. Activity Based Costing Two-Stage Assignment Process.

The approach differs from traditional cost accounting in the allocation of indirect costs. Traditional cost accounting typically uses a limited number of cost drivers, such as labor, to allocate indirect costs. Products or services requiring large amounts of labor would receive a proportionate share of indirect costs. The traditional approach works well in instances where the consumption of indirect resources varies in direct proportion with labor; however, this is rarely the case. Products significantly vary in the amount of indirect resources consumed: supplies, warehousing, computer processing, administrative support, or management. ABC accounts for the diversity in consumption by using multiple cost drivers to reflect how individual activities and products actually consume resources. Figure 2 provides an example of how the two approaches might assign indirect material handling costs to the customers consuming the resource. (2)

CUSTOMER A

3 DIRECT LABOR HOURS	TRADITIONAL:	3 X $20 = $60
4 PALLET MOVES	ABC:	4 X $10 = $40

CUSTOMER B

2 DIRECT LABOR HOURS	TRADITIONAL:	2 X $20 = $40
6 PALLET MOVES	ABC:	6 X $10 = $60

Material handling equipment overhead: $100
Fully Burdened cost per direct labor hour: $20
Actual cost per pallet move: $10

Figure 2. Comparison of Traditional Costing and Activity Based Costing (ABC).

The example illustrates how traditional costing can send the *wrong signals* to logistics managers regarding costing and profitability. The use of a single cost driver causes traditional costing to over-cost Customer A and under-cost Customer B. ABC sends a more accurate signal to the logistics managers by using another cost driver for tracing the consumption of material handling equipment (MHE) resources. For example, MHE costs are assigned by the number of pallet moves. A single cost driver, such as direct labor, cannot accommodate the diversity in how indirect resources are actually consumed in providing logistics services.

How is ABC Being Implemented?

Twelve organizations provided in-depth information regarding how and where they used ABC to support logistics

decision making. We will next discuss the organizations, why they used ABC, and the implementation process they used.

The Organizations

The twelve organizations participating in the analysis included a wide range of industries with annual sales ranging between $800 million and $2.5 billion. The business organizations asked to remain anonymous due to the competitive advantages resulting from their ABC applications. The defense organizations included the Defense Industrial Supply Center (DISC) and the Defense Construction Supply Center (DCSC). Table 1 summarizes the organizations and individuals contacted.

INDIVIDUALS CONTACTED				
ORGANIZATION	VICE PRESIDENT	DIRECTOR	MANAGER	ANALYST
Food Products				Logistics
Food Products	Finance	Operations		
Chemical		Distribution		Finance
Food Products				Finance
Office Supply	Finance	Finance	Operations	Consultant
Defense		Res Mgmt	Res Mgmt	Res Mgmt
Defense	Res Mgmt	Res Mgmt	Res Mgmt	Res Mgmt
Electronics	Finance		Finance	Logistics
Electronics		Operations	Operations	Operations
Food Products			Finance	Finance
Consumer Goods	Logistics	Logistics	Finance	Finance
Health & Beauty Aids		Distribution	Finance	Distribution

Table 1. Summary of Participating Organizations.

Reasons for Implementation

The reasons for implementing ABC varied by organization. The most frequently cited reasons included:

- Determining the factors driving logistics costs.
- Assigning logistics costs to product divisions.
- Obtaining more accurate, or finer, cost data.
- Tracing effect of logistics costs on profitability.
- Targeting sales/marketing efforts on the most profitable customers, products, or regions.
- Focusing reengineering efforts and costing the resulting benefits.

Below is one of the specific responses when asked "Why are you implementing ABC?"

> Our customers pay us for the goods and services we provide to them. In order to better support our customers and be the supplier of choice, we must continually look for ways to improve our processes in terms of cost, quality and timeliness. Although DCSC has been continually pursuing improvement, ABC as a tool is unique in that it will provide us with a guide to identify and focus our attention on process improvement opportunties, while measuring the impact of these cost improvements. Specifically, we need to reduce our operating costs at DCSC. . . . If we are interested in lowering costs, we need to know the relative value of activities and understand what drives them. Through ABC, cost drivers are defined and examined in order to reduce or eliminate them, thus reducing the cost of performing those activities. ABC allows our decisions on cost reductions to be based on really knowing how the reductions will affect the mission and our customers. It will provide information to managers over which they have control and can affect change. (3)

Our research showed the internal customer frequently played a major role in the decision to implement ABC. The organizations previously allocated logistics costs to their internal customers, the product divisions, using arbitrary allocation bases such as sales volume or case volume. The inherent "averaging" of using a single allocation basis caused many product divisions to challenge the resulting overhead cost allocations. Division managers contended the cost allocations did not accurately reflect how their products consumed logistics resources, and they could not determine how changes in product volume or logistics requirements would affect their cost allocation.

The use of ABC to assign overhead costs to the product divisions produced results similar to the changes in overhead costs at the product level reported by Turney. (4) Twenty percent of the product divisions experienced significant changes in their overhead cost assignments, and eighty percent of the divisions received approximately the same cost assignment. However, the twenty percent experiencing the most significant changes consumed approximately eighty percent of the total overhead costs.

Implementation Process

The implementation process used in logistics applications followed the approach taken in manufacturing applications. All of the organizations followed a process similar to those described by Turney, Cooper, and Brimson. (5;6;7) The implementation process is illustrated through an adaptation to a conceptual ABC system developed by Beaujon and Singhal (Figure 1). (8)

The implementation processs used by the case study organizations can be summarized in five steps:

(1) Identification of activities.

(2) Reconstruction of general ledger accounts.

(3) Selection of first stage cost drivers—tracing resource costs to the activities.

(4) Selection of second stage cost drivers—tracing activity costs to the products, services, or customers consuming the activities.

(5) Determination of product, service, or customer costs—summing the costs of the activities consumed.

The time and cost required for ABC implementation did not vary with the size of the organization. The number of activities included in the model and the hardware/software had the greatest effect on implementation costs. The organizations required timeframes similar to those reported by Turney, Cooper, and Miller. (9;10;11) They found three to six individuals could implement an ABC system within three to four months in most manufacturing firms.

Data collection emerged as the most significant impediment encountered during ABC implementation. The implementation teams indicated logistics cost data did not exist in a form readily usable for ABC. The problems encountered during data collection supported the conclusions drawn in earlier research which found cost management systems used in transportation and warehousing did not provide the cost information needed by distribution (logistics) managers to effectively manage their operations. (12;13;14) As a result, the implementation teams relied extensively on interviews to determine how specific activities consumed logistics resources. The organizations had previously relied on a single cost driver to allocate logistics costs.

Cost avoidance or the use of cost-benefit analyses did not play a major role in justifying ABC within any of the organizations. None used a cost-benefit analysis to justify implementation. They justified ABC primarily on the need for more accurate logistics cost information or to support a larger umbrella project

or initiative. The results coincided with a previous survey of ABC within business logistics. The survey found 92% of the respondents did not perform a cost-benefit analysis in justifying an ABC system. (15)

Benefits Achieved Through ABC Implementation

The recent implementation of ABC within many of these organizations precluded them from determining or obtaining the full range of potential benefits. However, observations made during on-site visits identified four benefits common to the majority of organizations:

(1) More accurate cost information to support management decision making.

(2) Costing at the activity and process levels—better understanding of how activities and outputs consume overhead resources.

(3) Profitability by product and customer—focus sales/marketing on most profitable customers; reengineer to reduce costs for unprofitable customers.

(4) Competitive advantage achieved through cost reduction or service differentiation—ABC provided the information needed for determining where costs could be reduced or where service could be improved.

These benefits primarily resulted from the increased visibility provided by ABC. The following distribution center example derived from two of the organizations illustrates the insight provided by ABC.

Logistics managers can use ABC to determine: (1) how the activities performed consume logistical resources, and (2) how different products or customers consume the activities performed by a logistics organization. Figure 3 portrays the cost of the available resources translated into activity costs and the cost to support specific commodity groups.

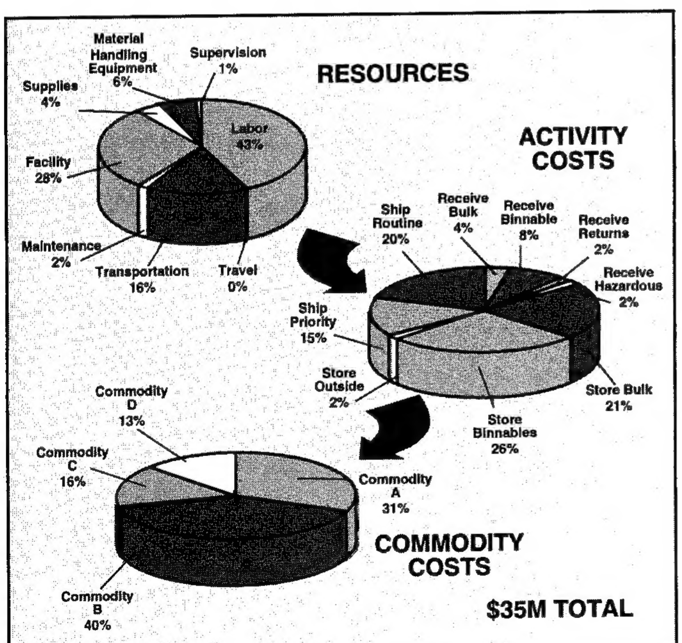


Figure 3. Translating Resource Costs into Activity and Product Costs.

The information shown in Figure 3 is very different from the information obtained from a traditional cost system. Activity costs in a traditional system would only reflect the amount of direct labor consumed in performing the activity and a proportionate share of indirect costs. The activity costs in the figure reflect the amount of each resource actually consumed by each activity.

Distribution center managers have found this information particularly useful in understanding how activities consume available resources. High cost activities are frequently targeted for cost reduction or reengineering. ABC assists in this process by showing the amount of each resource consumed by the activity. Management can cut activity costs by reducing the amount of each resource consumed, sharing resources with other activities, ensuring activities do not perform redundant functions and unnecessarily consume logistical resources, or by entirely eliminating the activity's requirement for a resource.

Logistics managers can further benefit from ABC by gaining additional insight into how different products or customers consume logistical resources. Activity costs are assigned based on how products or customers consume a specific activity. Figure 4 is an example of how an activity is consumed by the different commodity groups. In this example, the pie chart shows the proportion of the cost for the *ship priority* activity that would be assigned to each of the four commodity groups handled at the distribution center. The ABC model assigned the activity cost based on the number of priority shipments for each commodity group.

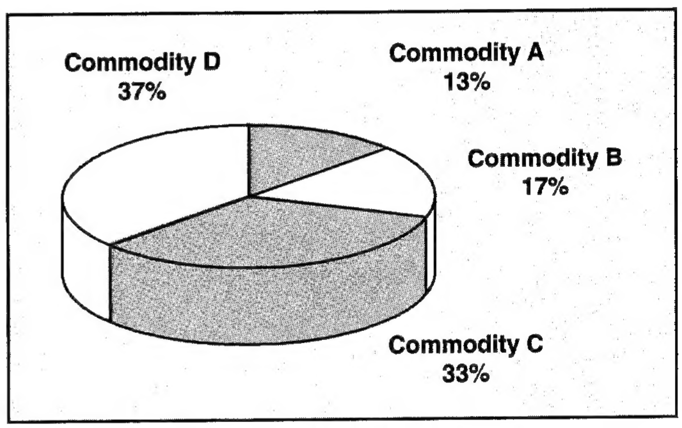


Figure 4. Proportion of the Ship Priority Activity Assigned to Each Commodity Group Handled at the Distribution Center.

Distribution center management can use this information to determine why commodities C and D require more priority shipments. They can work with the customers for these commodities to reduce the number of priority shipments. They can also evaluate how internal management actions or decisions may be affecting the number of priority shipments.

By assigning all activity costs, the total costs of supporting a specific product or customer was determined. The use of multiple cost drivers and activities enabled ABC to more accurately reflect how the commodity groups consumed the direct and indirect resources of the organization. In this distribution center example, ABC used nine cost drivers to accomodate differences in how the commodity groups consumed logistical activities and resources. The traditional system previously used by the distribution center used only the number of cases shipped to assign costs. Figure 5 compares the final cost results obtained through ABC versus the traditional system.

The traditional costing approach would have sent the *wrong signals* to the distribution center's management team. The traditional system would have under-costed commodity groups

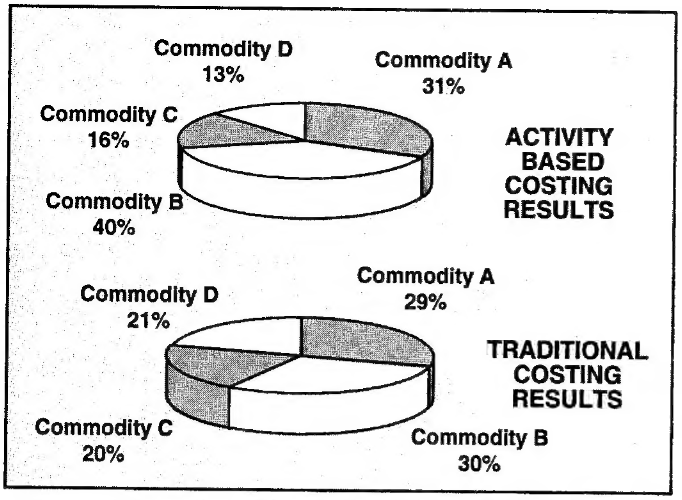


Figure 5. Comparison of Activity Based Costing Versus Traditional Costing Results.

A and B while over-costing commodity groups C and D. Surcharges or pricing decisions based on this information would resulted in lower cost recovery or profit. On the other hand, ABC sends the *right signals* to distribution managers. Surcharge and pricing decisions will more accurately reflect the cost of the logistics resources and activities required by each commodity group.

Logistics managers use the results of an ABC analysis to support a wide variety of management decisions. Pricing decisions and internal transfer costs frequently change as a result of the analysis. Logistics managers target high cost activities for reengineering to lower the costs of supporting specific commodity groups. They can use this information in determining the organization's core competencies or competitive advantages. The organization may decide to concentrate on those products or customers which can be supported at the lowest cost and greatest profitability. Activities or commodiity groups consuming extensive amounts of logistical resources may be contracted out to third-party logistics providers.

Many of the organizations also use ABC to simulate how changes in activity levels will effect logistics costs. The example in Table 2 was drawn from an analysis performed for the major consumer goods manufacturer in our study. ABC was used to

ACTIVITY	COST PER ACTIVITY	CHANGE IN ACTIVITY VOLUME	PROJECTED COST CHANGE
Load Pool Shipments	$200/truck	-20	-$4,000
Load LTL* Shipments	$25/shipment	+350	+$8,750
Process Orders	$15/order	+350	+$5,250
Pick/Build Orders	$30/order	+350	+$10,500
Total Change			+$20,500

*LTL = less-than-truckload

Table 2. Using Activity Based Costing to Simulate How Projected Changes in Activity Volumes Will Impact Logistics Costs.

simulate how the firm's distribution costs would change as a result of a customer ordering more frequently. Specifically, the firm's distribution center projected that the change would reduce the number of their pooled or consolidated shipments and would increase the number of less-than-truckload (LTL) shipments and number of orders handled.

The application of management decision-making tools to activity based information has led to the development of activity based management (ABM)*. ABM combines the financial and nonfinancial information produced by ABC into actionable performance measures. Managers can use ABM as a tool for continuously improving and measuring the performance of activities and processes while also assessing their impact on the costs of the organization. ABM has proven particularly useful in translating nonfinancial performance measures such as fill rate or on-time deliveries into financial or cost based performance measures such as the cost of a backorder or the cost of a late delivery.

Future Directions for ABC Implementation in Logistics

ABC will experience continued growth in logistics during the 1990s. The nature of logistics decision making has become increasingly complex due to the direct effect of logistics on corporate profitability and on the costs of performing other functions within an organization. Logistics managers will continue to require more accurate and precise cost data to make better and more timely decisions, and ABC has emerged as a mechanism to provide the cost information required for making better logistics decisions.

The approach taken by these case study organizations suggests three potential directions for future ABC implementation within logistics:

(1) Logistics organizations require the capability to trace costs and determine profitability by customer.

(2) Many organizations have an interest in using ABC to measure performance, and ABM provides the capability to translate activity based information into meaningful measures for assessing performance.

(3) Application of ABC to the supply channel can provide another avenue for obtaining a competitive advantage through lower marketplace costs and improved service.

These directions have major implications for organizations considering ABC implementation or designing an ABC system.

Customer Costing

Logistics ABC applications will incorporate the capability to trace logistics costs to the customer driving the requirement. The logistics managers participating in this study found the type of customer frequently had a greater affect on total logistics costs than the type of product. The customer drives the range and types of logistics services performed, and many of the interviewed managers believed customer costing would provide a more meaningful way of depicting how logistics resources are consumed.

Managers can modify their ABC system to trace activity costs to the customers or channels consuming the activities. Customers or channels using standard, high-volume processes would typically receive a lower cost assignment. However, customers or distribution channels requiring specialized

*ABM is "a discipline that focuses on the management of activities as the route to continuously improving the value received by customers and the profit achieved by providing this value. This discipline includes cost driver analysis, activity analysis, and performance analysis. Activity-based management draws on activity-based costing as a major source of information." (3)

facilities, handling, packing, palletization, etc., would receive a much higher cost assignment reflecting the consumption of high cost activities or a disproportionate share of logistics resources.

Customer costing provides another means for evaluating profitability or cost recovery. Logistics managers can use the information to target high cost activities for cost reduction or process reengineering. They may identify techniques to eliminate the amount of packaging, handling, or use of unique or non-standard equipment. Logistics managers can also use the information to demonstrate the affect customers have on logistics costs and total profitability. The information can be used in pricing decisions or when selecting transportation modes or channels of distribution. The organization can also work directly with the customer to ensure unnecessary or redundant services are not being performed and to identify joint actions to reduce logistics costs for both parties.

ABM and Performance Measurement

ABM appears to be a natural follow-on to ABC implementation in most logistics organizations. The case study analyses demonstrated a movement towards implementing activity based performance measures within logistics. Only one firm actually was using ABM during the study; however, the organizations indicated a definite movement towards activity based measurements. Over half of organizations had plans to expand their existing ABC systems to incorporate ABM. The lack of activity based performance measures currently in use within logistics stems from the relatively recent introduction of ABC to logistics coupled with the even more recent introduction of ABM. The implications resulting from implementing ABM within logistics include the ability to capture the measurement data, the development and acceptance of the performance measures, and the behavioral impact cost based performance measures may have on the workforce.

The use of activity based performance measures will modify the behavior of management and the workforce. Behavior will change to conform to the performance measures. The organizations considering ABM indicated performance measures must be carefully developed to preclude undesirable workforce behavior. They cited examples where over emphasizing cost had caused quality and customer service to decline; however, undesirable behavior can be avoided through extensive communications and obtaining feedback from the workforce. Logistics managers would need to continually monitor customer perceptions to ensure performance measurements aimed at reducing cost or time have not overridden objectives involving customer service, product quality, or the development of competitive services.

Implementation of ABC/ABM within logistics provides greater insight into the effect of management decisions on profitability and total costs by:

- Using nonfinancial data to drive continuous improvement and reengineering efforts. ABC information can highlight high cost or nonvalue-added activities for management action. ABM provides a mechanism for measuring subsequent performance and determining how management action has affected profitability.
- Linking a performance measurement system to changes in process costs or profitability. The organization can evaluate management actions and decisions based on its ability to lower costs or improve performance within a process. The process view can avoid "suboptimization" by individuals attempting to drive costs down at the activity level, but ending up increasing total process costs. Instead, ABM will focus management action on overall performance or lower costs at the process level.

Application of ABC to Supply Channel Management

Logistics organizations will use ABC for analyzing business processes extending through the supply channel and for evaluating alternative channel structures. The study found the majority of organizations planned to expand ABC to determine the total channel cost of moving product to market and the total cost of doing business with specific vendors, carriers, or other supply channel members.

ABC has experienced only limited use in a supply channel setting. The limited use has resulted from the very recent implementation of ABC within logistics and efforts to complete internal implementation before expanding ABC to supply channel management. The case study organizations' logistics managers plan to use ABC for better managing and controlling supply channel costs.

The application of ABC to supply channel management has several implications for logistics. These include the tracking of cost data across the boundaries of multiple organizations, the confidentiality of cost data, and the effect of making cost tradeoffs across the supply channel. The ABC system must also possess a dynamic costing capability allowing the logistics manager to isolate and assign costs by carrier, vendor, or distribution channel, and to simulate how alternative decisions would affect total costs. A dynamic costing capability will allow logistics managers to determine the total costs of doing business with specific vendors, carriers, or other upstream or downstream channel members.

Supply channel applications of ABC will require the ability to track costs across multiple firms. The issues confronting cost tracking will include different definitions of cost categories and activities, use of multiple cost systems to obtain the data, and the level of detail or aggregation required.

The principal reason for applying ABC to supply channel management focuses on making trade-offs across all of the interlinked organizations to reduce total costs, decrease order cycle times, and achieve a competitive advantage. The trade-offs may result in reducing overall supply channel costs, but they may also cause costs to increase for one or more organizations and to decrease costs for other organizations. Supply channel applications must develop techniques for equitably distributing the benefits and burdens resulting from the trade-off analyses.

Conclusion

Activity based costing will play an important role in logistics decision making during the 1990s. The analyses performed by the Air Force Institute of Technology indicate continued growth in the number of organizations using ABC and ABM in business and military logistics. The need for more accurate cost information to support logistics decision making and the capability to translate activity based cost information into meaningful performance measures provide logistics managers with the tools required for achieving a sustainable competitive advantage. Logistics ABC applications will also continue to expand into the areas of customer and channel costing.

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Logistics Professional Development

Logistics AFSC Consolidation

With the ongoing efforts toward implementing the new Logistics Career Development Program (reference the item on Logistics Cross Flow in the Spring-Summer 1994 issue of the *Air Force Journal of Logistics*, HQ USAF/DP and HQ USAF/LG have agreed to merge all logistics officers AFSCs into one 21XX AFSC. Effective 31 October 1995, the AFSC structure for logistics officers will become:

20C0	Logistics Group Commander
21LX	Logistician
21AX	Aircraft Maintenance
21GX	Logistics Plans
21MX	Space and Missile Maintenance
21SX	Supply
21TX	Transportation

Officers will enter the Air Force into one of four logistics AFSCs: 21AX, 21MX, 21SX, or 21TX. In another recent change, Logistics Plans will no longer access officers into their career field. Accessions are being projected into the other four entry AFSCs for planned career broadening into Logistics Plans after their fourth year in service.

Entry into the 21LX AFSC is reserved for field grade officers who meet specific criteria. To qualify for the entry level Logistician AFSC (21L1), officers will need to hold two other logistics AFSCs, have a minimum of four years in one logistics AFSC, and complete the Advance Logistics Officer's Course (ALOC). The ALOC, currently under development, will be reserved as a mandatory course for field grade officers only.

Award of the fully qualified Logistics AFSC (21L3) will require completion of the entry level requirements and an assignment as a commander or staff officer, or attainment of the grade of lieutenant colonel.

Grandfathering criteria to the requirements for award of the entry/fully qualified Logistician AFSC was determined at the March meeting of the Logistics Board of Advisors (BOA). More details will be provided in the next issue of the *Air Force Journal of Logistics.*

Personnel Update

There are several changes in personnel at Headquarters Air Force Military Personnel Center (AFMPC) as well. Following the lead of the Logistics Career Development Program, Logistics Support Officer Assignments and Maintenance Officer Assignments have combined into the Logistics Officer Assignments Branch (DPMRSL). All phone numbers will remain the same. Further, with the departure of Majors Atkinson and Heimerman from DPMRSM and DPMRSL respectively, Major Ed Hayman will take charge of the new branch in June. Other changes in personnel include the arrival of Captain Deborah Elliott who will work with Captain Craig Bond in Supply Officer Assignments and also the addition of Captain Keith Quinton working with Captain Ricky Cornelio in Logistics Plans Officer Assignments. Maintenance Officer Assignments is manned by Major Steve Shinkle and Captains Roger Rostvold and Catricia Mills. Major Toby Seiberlich remains in Transportation Officer Assignments and Captain Tom Jett will replace Major Heimerman.

AFIT Program

Selections for officers to attend the Air Force Institute of Technology's (AFIT's) School of Logistics and Acquisition in 1995 are complete. We filled 30 quotas for degree programs in transportation management, supply management, and logistics program management. We were able to use these slots as another career broadening opportunity for logistics officers. Officers completing their degree as a career broadener will also be assigned to a cross flow tour commensurate with their degree experience.

Now is the time for officers interested in attending AFIT in 1996 to complete the eligibility requirements through their base education office. Eligibility requirements for the AFIT School of Logistics include:

- 3.0 GPA in Bachelor's degree.
- 500 verbal/600 math scores on the Graduate Record Examination (GRE).
- Completion of college algebra.

In addition to AFIT eligibility, logistics officers must contact their assignments officer to volunteer for AFIT consideration. Don't wait—start working on your future today and volunteer for AFIT. It's a great opportunity!

(Major Cheryl Heimerman, HQ AFMPC/DPMRSL, DSN 487-4024)

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